W. F. Kirkwood

Primer of Botany

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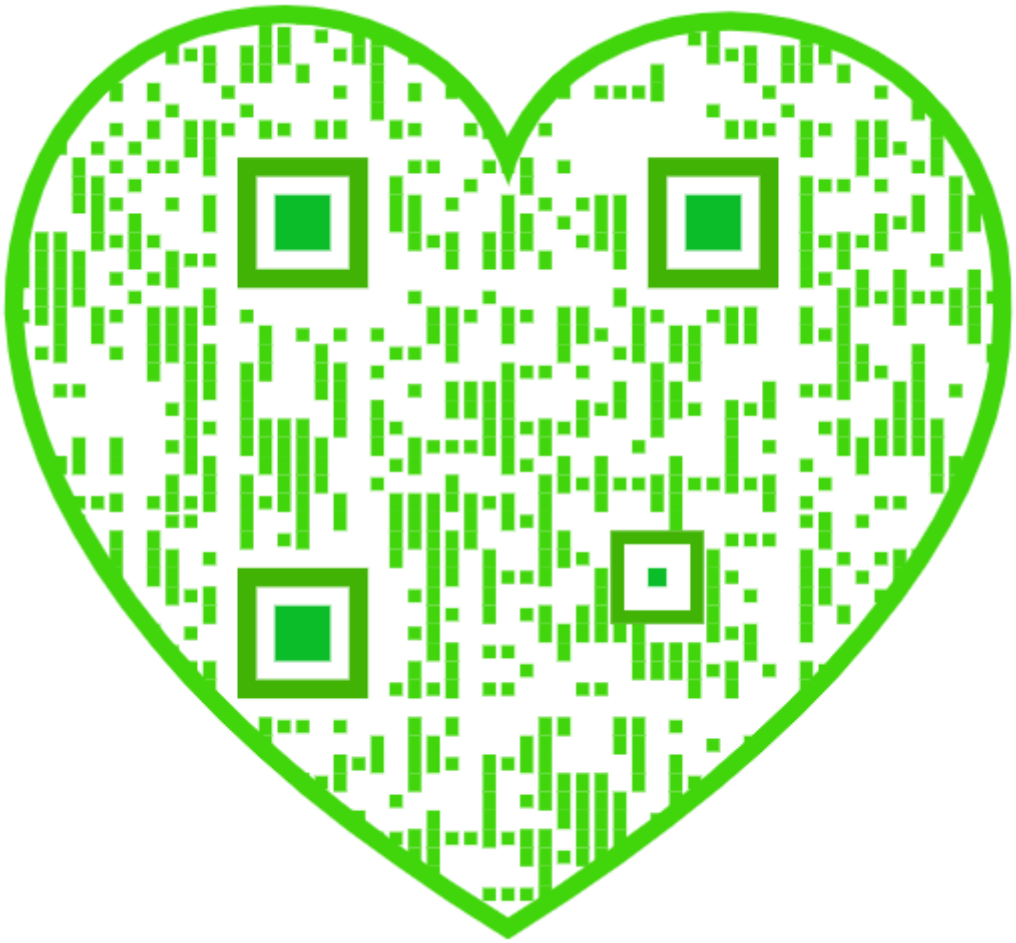

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PRIMER OF BOTANY.

BY

MRS. A. A. KNIGHT,

ROBINSON SEMINARY, EXETER, NEW HAMPSHIRE.

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PREFACE.

THE one actual expense about the use of the Primer will be a compound microscope.

The lessons may often prove unduly long for the capacity of the class or for the length of the recitation period. One lesson may furnish material for three or four successive recitations. This matter of adjustment must be left to individual cases. There are many ungraded schools in which the present number of classes resolutely forbids any fixed number of minutes for this sort of general and accomplishing instruction which every earnest teacher greatly desires to give. In such a perplexity, the Primer can be taken up daily for a few moments before the morning recess, with the understanding that the examination of the specimen may be continued through that brief respite if any or all desire to spend it about the microscope. It may be objected that both teacher and pupils are extremely in need of the "temporary suspension of hostilities," and that it is best for both to part company for a few minutes. There is much truth in the objection, and if any better time can be found for the exercise, no teacher ought to spend a recess over botany. If no other arrangement can be made, she will have the consolation of knowing that the heaviest part of the wear and strain of nerve will be borne by herself instead of her charges; and

as in this case the matter will narrow to the question whether she is willing to "die daily — a little" for the furtherance of her work, or to assert her claims of personal ease at its expense, this employment of the odds and ends of school hours must be necessarily left to the individual worker.

Other teachers may feel, too, that the Primer strikes ambitiously into profound depths unsuited to small, unreasoning minds, as if one should read Spencer in the nursery. The truth, however, will generally bear telling. It is an injustice to the childish intellect to teach it botany superficially, and it is a strange error to encourage it — by silence about other series of facts, at any rate — to consider the complex plants we see about us as the important whole of the vegetable kingdom and to relegate the families of blights, rusts, smuts, and moulds to a limbo of uncertainties and insignificance.

The writer begs the teacher who tries this Primer to believe that the system of tests and reviews and the selection of materials are not considered finalities of arrangements. The aim of this work is to be suggestive. In most cases the practical studies can be bases of original outlining. The material used has been taken from text-books designed for older pupils, and has been simplified to bring botany into the reach of primary grades.

The writer feels much indebted to Professor Charles E. Bessey, of the University of Nebraska, for matter taken from his "Essentials of Botany," and for his painstaking examination of the manuscript of this Primer. Principal G. N. Cross, of Robinson Seminary, Exeter, N.H., has kindly furnished an appendix, upon the cost and care of microscopes.

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CHAPTER I.

THE PLANT.

A.

WHAT THE LIVING PART OF A PLANT IS.

☞ The teacher should provide herself with plants in pots instead of cut flowers.

Name a plant; as, a pink.
Point in the direction of it. Where is it?
How large is it?
How would you know it from another plant?
State something about, —

a lily, a rose, a tree, a root.

Yeast Plant.

a. cell-wall.
b. cell-contents, called "protoplasm."
c. clear space in the protoplasm.

NOTE TO TEACHER. — *Getting acquainted with a plant.* Make a thin slice of verbena stem. (*a*) What is this? Put it under the microscope. (*b*) What is it now? (*c*) In what are the drops of pulp lying?

The furniture of your sitting-room lies inside the walls of the room. Islands lie in the sea.
The soft, clear drops of verbena lie in their thin walls.

What is the living part of a plant?

I. **Soft, transparent drops of protoplasm are the living part of a plant.**

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Tell me where protoplasm is found in, —

rootlets, branches, foliage, fruit.

(Teacher must test this by cuttings from various specimens.)

II. **Protoplasm is found everywhere in a living plant.**

In order to live, we must have something to eat, for food builds bones and makes blood.

Protoplasm gets food from water. Protoplasm makes room for its food, and stores it up in small, clear drops, like tears.

PRACTICAL WORK. — Make very thin slices of tender asparagus. Use the $\frac{1}{6}$ objective. Note the drops of food. Stain some slices with red ink. Use glycerine upon others. The ink stains the protoplasm; glycerine withdraws the water from it. See the protoplasm wither and collapse. *Collapse*, by the way, means falling together in a formless manner.

III. **Protoplasm can change its position and its form. It moves most easily and stores food best when it is warm.**

TEST I.

"Cut a bit of verbena stem in such a way as to leave the marginal hairs intact. Examine in water at 86° Fahr. for a motion of protoplasm in the hairs. Transfer the stem to a block of ice, and notice how entirely the movement ceases. Warm again."

1. Learn to pronounce, spell, and write the word *protoplasm*. "*Protoplasm*" *means the first thing which is made.*

2. Use the word *protoplasm* correctly to show, —

the composition of a stem; a leaf.
how plants eat.
how they move about.

Read these groups of words, and copy every name of something made of protoplasm: —

1. Leaves are such common things that we do not think how beautiful they are.
2. Snow is feathery and cold.
3. You have disturbed the level.
4. Flowers are of all shapes.
5. A cistern full of water.
6. The white flower is fragrant.
7. Onions are buds.
8. The pebble is smooth.
9. Close your eyes.
10. The grains from which our bread is made are seeds.

Read the list of names of things made of protoplasm.

B.

ABOUT GREEN PROTOPLASM.

Has protoplasm a color?

Protoplasm is colorless, but it can make a color, and dye all or a part of itself.

Some parts of the protoplasm in a tiny plant are bright green, stained so by a green dye made in them.

Protoplasm does not readily make this dye in the dark, and even the made dye fades out in long-continued darkness. That is why plants grown in the dark are sickly and wan.

Give an example of a plant containing but little green dye.

A. **This dye is called chlorophyll. A chlorophyll grain is a drop of stained protoplasm, and chlorophyll is the staining dye.**

Write a statement about, —

a bit of blanched celery.
a bit of unblanched celery.

Pond Scum.

One of the lowest plants having leaf color.

a. cell-wall.
p. protoplasm.
s. space in the protoplasm.
d. dividing walls.
e. new cells.

B. **Chlorophyll draws the protoplasm which it treats into lumps or into star-shaped grains.**

C. *Alcohol will separate protoplasm and chlorophyll. When moss leaves are soaked in alcohol, the chlorophyll leaves the cells and stains the liquor. You can turn the whitened drops of protoplasm brown by taking the trouble to add iodine to the alcohol.*

Bring to school potato stems grown in the dark. Compare them with potato stems grown in the light.

C.

STARCH.

Make a statement about starch.

What word in the statement names a food? Write that word on the board.

Write the name of an article of food containing starch. How do you suppose the starch came in it?

Why, do you suppose, a plant stores up cupboards of starch?

IV. Starch is a plant food. It is made in light, and the plant lives upon it in darkness. It can be made in chlorophyll grains only.

Test I.

Tell, in five short statements, —

one thing that is in a grain of wheat.
one thing that is in a kernel of corn.
one thing that is in a slice of potato.
one thing that is in a grain of oatmeal.
something in rice.

Write the five statements.

Caution. — Sometimes more starch is made than the plant can use. It is put away in cells for the future; thus, in autumn, apple twigs contain starch in cells of the pith.

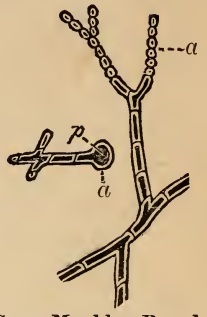
Test II.

Examine under the microscope a very thin slice of potato. You will see egg-shaped starch grains. Soak the

slice in red ink, and the protoplasm which imbeds the starch will appear plainly.

Write a statement about, —

(1) leaves that have been in the light many hours.
(2) leaves that have grown in the dark.
(3) cells of wheat.
(4) potatoes.
(5) protoplasm.



Green Mould on Bread (magnified).
a. cell-wall.
p. protoplasm.

(*a*) In each statement underline the words which mean plant food.

(*b*) Make a list of plants which store up much starch.

(*c*) Note with the microscope whether potato cells or Indian corn cells have more starch.

(*d*) Put a drop of iodine upon a slice of potato. The starch grains will turn blue. Write the use of starch; where it is found; whether protoplasm is its bed; whether starch is manufactured in colorless protoplasm.

Mount threads of pond scum previously exposed to sunlight. Write the names of the substances seen in the cells of the pond scum.

Substances are matters which occupy space.

Write five statements about the substances.

In each statement underline the words which mean plant food.

Write a direction for bringing out starch grains vividly.

Write the color which they will become.

See, —

that every statement is correctly spelled.
that you know clearly the word *substances.*
that no mistake about a fact has been made.

☞ Oral exercise concerning errors.

D.

THE PLANT CELL.

1. Mount the following: —

   a leaf of moss.
   green slime scraped from a damp wall.
   a drop of putrid water.

2. How is the protoplasm of the moss leaf found?

   The protoplasm of a moss leaf is found in little boxes.

3. What is each box called?

   Protoplasm boxes are called cells.

4. Tell how protoplasm is found in, —

   green slime, an apple twig, stems of corn.

Sometimes single cells or plants float alone; as, bacteria in the drop of water.

More often, the cells or plants are found together, in a great company; as, green slime.

Most often, cell-walls thicken as plants grow old, as in a lily stem.

A cell full of protoplasm is a plant.

V. **Cell-walls are made by protoplasm, much as the snail makes his shell.**

The cell-walls press upon each other very much.

TEST.

Describe, by mounted specimens, the cell-walls and contents of, —

a lengthwise section of corn stem,
the section of apple twig,
green slime.

NOTE. — A few plants have no cell-walls, or very thin and poor ones. Yellowish masses of slime mould are handfuls of naked protoplasm, without houses to live in. Slime moulds are the lowest plants.

1. Name a plant which is a single cell.
2. Name a plant without cell-walls.

E.

SAP.

Apply your handkerchief to a section of freshly cut fleshy stem. Make a statement about the result.

What word tells what has moistened the linen? Write that word on the board.

Use the word *sap* instead of the word *water*. Taste a bit of sugar cane or the sap of sugar maples.

How does the water in these plants differ from drinking-water?

VI. **The water in a plant is called sap.**

EXERCISE.

Tell in five short statements, —

one fact about the sap of the sugar maple.
one fact about the sap of a squash plant.*
one fact about the sap of a cherry.
what you can taste in corn stalks.
what you can see if you slice a sunflower stalk.

VII. **Sap holds all the uncooked food which the plant drinks from the air and the soil.**

VIII. **Sap is the cupboard where the plant stores its cooked food.**

Mount for examination fresh and wilted stems. Make statements about, —

(*a*) the water in the fresh stems.
(*b*) the size of the fresh stems.
(*c*) the size of the wilted stems.
(*d*) the sap in a wilted stem.
(*e*) some stem which you have seen wilt.

All parts of a cell are steeped in sap.

---

* NOTE TO TEACHER. — "We misuse the term *vine* a great deal. Vine, from *vinum*. The vine is the wine plant, the grape plant. Usage, it is true, sanctions the use of vine for squashes, peas, morning glories, etc., but for all that it is a *bad usage*." — BESSEY.

Examine these parts of plants: —

(1) a rose leaf,
(2) a cell wall,
(3) roots,
(4) rootlets,
(5) stems,
(6) branches,
(7) seed,
(8) buds,
(9) an apple,
(10) flowers.

Copy every word which denotes something saturated with sap.

All these things are groups of protoplasm. Protoplasm is saturated with sap, and contains drops of it.

Review.

ORAL.

1. Tell (*a*) what the living part of a plant is; (*b*) the name of green-stained protoplasm; (*c*) where starch is found; (*d*) what starch is; (*e*) the name of the box which holds protoplasm; (*f*) the name of the cell substance; (*g*) the name of the water which saturates the cell.
2. Name a substance dissolved in cell sap.
3. Read these words, and tell of what each is the name: —

   protoplasm, chlorophyll, plant cell.

4. Give an example of, —

   a thin cell-wall.
   thickened cell-walls.
   cell-walls extremely thickened.

5. Name a plant without cell-walls.
6. What effect has warmth on protoplasm? Give examples.

7. Describe a plant.
8. Explain the growth of a plant.

WRITTEN.

1. Write a word which is the name of, —

   a cell-box, the dye found in some cells.

2. Write the name of the living part of a plant.
3. Write its name when stained green.
4. Write two properties which it possesses.
5. State on the board how a living plant gets food.
6. Describe in a written statement the cell sap of, —

   cane, a geranium, a beet.

OR

1. Give, —

   the names of three plants containing starch.
   how we know they hold starch.

2. Explain the experiment with a slice of potato.
3. Tell, —

   why the plant stores starch.
   when it stores it.
   when it uses it.
   when it is impossible for a plant to store starch.

4. Can protoplasm stain itself?
5. What is the dye called?
6. What is the stained protoplasm called?
7. How is the stained protoplasm found?
8. What agent will separate protoplasm and its dye?
9. Explain a difference between, —

   a potato stem grown in darkness,
   a stem of the same grown in the light.

10. State two facts about blanched celery.

Find the sap in a section of geranium.

1. In what parts of the plant cell is sap found?

Cell sap penetrates every part of the cell and the cell-walls.

2. What does the sap hold dissolved?

The sap holds all the food which protoplasm needs. Sap is stored in drops in the protoplasm.

3. Give facts about, —

corn silk,	pollen grains,	nut shells,
verbena stem,	bacteria,	an apple twig,
slime moulds,	a potato,	a grape,
pond scum.	blanched celery,	a dahlia.
a stamen,	moss leaves,	

4. Prove, by tasting, the presence of sugar in three plants. Write the names upon the board.

NOTE. — Acids can be detected by applying blue litmus paper to mounted specimens. Acids will turn the paper red.

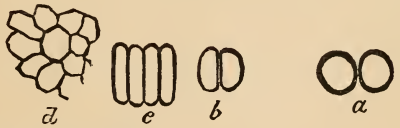
CHAPTER II.

TISSUES.

A.

A PLANT TISSUE.

A plant cell may live alone.
Plant cells usually live together in groups.



a. two cells scarcely touching.
b. two cells pressed together.
c. cells placed side by side, and pressure exerted at both ends of the series.
d. cells pressed together from all sides.

Tell whether the following plant cells live singly or in groups: —

Indian corn, geranium, moss.

A group of plant cells is called a plant tissue.

How can you tell a tissue?
Find among your specimens two groups of plant cells.
Describe a plant tissue.

I. **In very simple plants the cells are all alike, and such plants have but one kind of tissue.**

II. **Higher plants show differences; and the differences are many in elaborate plants.**

III. **The most important tissues* are (1) soft tissue; (2) fibrous tissue; (3) stony tissue; (4) milk tissue.**

B.

SOFT TISSUE.

Cells having thin, colorless walls compose soft tissue; as, the *central part* of a stem of Indian corn is made of *soft tissue.*

Soft tissue is seen in the green pulp of leaves; thus, —

the soft part of a leaf is of soft tissue.
pulpy sea plants are of soft tissue.

Soft Tissue.

1. Name the tissue seen in the following: —

the centre of a flower stem,	fleshy leaves,
spaces between leaf veinlets,	the flesh of a sepal,
interspaces of a squash leaf,	pond scum,
the parts of a rose petal,	a moss leaf,
the surface of a cactus bract,	yeast plants.

Many low plants are mere bundles of soft tissue.

---

* There is an admixture of less abundant tissues, not touched upon in this book.

2. Mount the following, and mention (*a*) the sort of tissue they display; (*b*) the shape and arrangement of the cells: —

a drop of yeast,	grape mildew,
centre of a slice of potato,	wheat rust,
green slime,	water mould,
a broad moss leaf,*	kelp.

IV. Soft tissue is found in the green parts and in the growing parts of plants.

3. Name, spell, and use correctly the tissue found in, —

the green cells of an apple leaf.
the centre of a stem of sweet brier.
the centre of a green corn stalk.
a cross-section of growing rootlet.
the pulp of a cherry.

Cup Moss.

4. What is soft tissue? Where found?

Soft tissue is the most abundant and important tissue in the vegetable kingdom.

5. Mention five examples of soft tissue.

---

* The moss leaf is usually a single layer of cells. Elongated cells form the midrib. The whole is of soft tissue.

C.

STONY TISSUE.

A slice of cocoanut shell is hard as rock.

The seed coat of a peach is so hard that it is called a stone.

The seed coat of an apple is tough.

1. Read the above sentences; tell what is said in each of the tissue of the part described; notice that all these parts are seed coats; see if you can give the hard tissue a name.
2. Think of two other seed coats that are thick and hard. Tell whether they appear to contain chlorophyll.

V. **Tissue which is made of cells with greatly thickened walls is called stony tissue.**

In the pith of apple twigs the stony tissue contains starch.

Test.

Name the tissue of the following examples: —

(1) walnut shells.
(2) a slice of hickory-nut shell.
(3) the coat of a melon seed.
(4) coats of cucumber and squash seeds.
(5) the pith of a twig.
(6) a cherry stone.

Copy from some book five names which recall stony tissue. Use three of these words in sentences, and describe the tissue.

Supply words in the following: —

(*a*) Starch is found in the —— of ——.
(*b*) We find stony tissue in ——, and ——, and ——.

D.

FIBROUS TISSUE.

VI. Fibrous tissue is made of cells that have been pinched and flattened by tissues near by.

NOTE TO TEACHER. — Tear off a thin piece of split maple twig, and mount in water. The torn surface will show wood fibres.

Write on the board the shape of the fibres.
What are the groups of cells called?

VII. Fibrous tissue is found in woody bundles. It gives strength to stems and leaves.

Write the composition of fibrous tissue.
Write two examples.
Write the shape of the fibres of each.

NOTE TO TEACHER. — Mount cross-sections of various woods, and point out differences in the amount of fibrous tissue.

There are two sorts of fibrous tissue, thick-walled and thin-walled. Thick-walled fibrous tissue is called Bast; thin-walled is called Wood. The fibres of bast are longer and more pliant than those of wood.

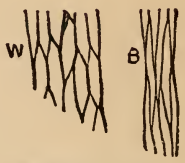
Both sorts exist in the same twig. When you are making lengthwise sections for mounting, you can see the

great length of bast fibres by cutting through one of the bundles of this sort of tissue. Bast bundles can be told by their whiteness.

TEST.

1. Make a statement about, —

   (*a*) a section of oak log.
   (*b*) an apple branch.
   (*c*) a maple twig.
   (*d*) branches of willow.
   (*e*) the trunk of an elm.



Wood and Bast Tissues.

2. Underline the names of tissues in the following sentences: —

   (*a*) Fibrous tissue is made of long, thick-walled cells.
   (*b*) Branches of trees are twisted into different shapes by white, finger-like fibres.
   (*c*) Such fibres are bast bundles. They are more flexible than those of wood.
   (*d*) Soft tissue and fibrous tissue make plants, and stony tissue protects plant food.

3. Describe soft tissue, stony tissue, and fibrous tissue.

E.

MILK TISSUE.

Some plants (as *lettuce*, *milkweed*, *the poppy*, *the dandelion*) **exude fluid resembling milk.**

Such plants contain milk tissue.

1. Mention an example of milk tissue, and locate the plant. Give its time of flowering.
2. Read the following sentences, and mark the mentions of milk tissue: —

   We squeeze opium from the tubes of the poppy.
   This system of tubes is found in stems, leaves, and roots.
   The peculiar juice of the plant may be white, yellow, red, or turbid.
   Milk vessels can hold caoutchouc and resin.

   The colored juice is called Latex.

3. Use a word that expresses the color of the juice of, —

a poppy,	the celandine,
a dandelion,	bloodroot.

4. Speak the right name of the milky juice of plants and mention a plant possessing it.

Note to Teacher. — Examine a drop of latex under the microscope by *transmitted* light. White latex will appear brown. Let the entire class thoroughly examine the specimen, and mark the difference in the effects of transmitted and reflected light.

5. Use the word for, —

   the real color of the juice of milkweed.
   the shape of the cups which hold it.
   the name of this juice.

Two Forms of Milk Tissue.

Milk tissue may be made up of thick-walled, branching tubes.

Milk tissue is often a group of thin-walled, branching tubes.

Mount for study a stem of Euphorbia.
Find the thick-walled tissue of the stem.
Speak the name of this tissue. Define the words *thick-walled*, *thin-walled*, and *branching* as applied to tissue. All are descriptive of what tissue?
Write in one statement all that is said of milk tissue in the two statements.
Mount for study a stem of lettuce.
How is milk tissue formed here?*
Are the walls regularly shaped?
Make a statement describing this second form of milk tissue.

Fill the blanks in the following: —

(*a*) The milk tissue of Euphorbia is —— and ——.
(*b*) The shape of the milk cells is ——, and the cells are —— in outline.

VIII. **Thick-walled milk tissue sometimes replaces bast.**

When latex is evaporated, there is a sticky residue.

REVIEW.

1. Define a plant tissue.
2. When do cells begin to show differences? What results? Name four tissues.
3. Give the most abundant tissue.
4. Describe a moss leaf. Locate soft tissue in a stem of geranium.
5. Name the tissue of cocoanut shells.
6. Give three examples of fibrous tissue. Tell its use.

* Lead the class to see that it is made by fusion of cells.

7. How can bast bundles be recognized?
8. Define latex.
9. Give two general forms of milk tissue.
10. Write an example of each.

CHAPTER III.

TISSUE SYSTEMS.

A.

WHY EVERY SYSTEM IS MADE UP OF GROUPS.

Groups of cells may become a boundary tissue system.

Other groups of stony tissue or fibrous tissue draw together as a supporting tissue system.

Groups of soft tissue may be pressed into tubes as a conducting tissue system.

The plant which we see, feel, and enjoy is the result of this division of work among the tissues.

Tell what is stated about, —

a boundary tissue system.
groups of fibrous tissue.
conducting tissue systems.

Of what is every tissue system made up?

I. **Every tissue system is made up of groups.**

How does a tissue system form itself?

II. **Pressure and other conditions of growth cause tissue systems.**

How many chief tissue systems?

III. Three, — the Boundary, the Supporting, and the Fundamental Systems.

Exercise I.

1. Write three statements about tissue systems.

Examples. — Tissue systems are not found in the lowest plants. Division into tissues is constantly attempted in plant life, and is accomplished where there is power to match ambition.

2. Copy the following: —

Tissue systems appear as plants become complex.
They reach their fullest development in the most complex plants.

Exercise II.

ORAL AND WRITTEN.

1. Use *stony tissue*, *fibrous tissue*, and *soft tissue* in a statement about, —

the boundary system.
the supporting system.
the fundamental system.

2. Locate the three tissue systems in, —

a cross-section of cabbage leaf.
a stem of Indian corn.

3. Tell what you think is the use of each system.

Write these opinions upon slates or blackboards.*

---

* To avoid mistakes, promote a short conversation about the uses and names of the tissue systems.

B.

THE BOUNDARY SYSTEM.

(*a*) The boundary system is the simplest tissue system. It is the plant's glove.

(*b*) It is the first system discovered in the upward scale of plant life.

(*c*) It is the first to appear in the individual plant.

(*d*) In plants of low type it can scarcely be seen.

(*e*) Examination detects it, in such plants, by its dark, small, and crowded cells.

(*f*) The boundary system of fungi can be lifted from the mass beneath it.

(*g*) In higher plants it is sharply separated from other systems.

Hair Moss.

Name the system of tissues mentioned in every statement.

What facts are given in the statements marked (*b*), (*c*), and (*e*)?

How is the system told in plants of low type? In such plants is it developed or in process of formation?

Read the statements marked (*f*) and (*g*); tell whether the boundary system is developed in fungi.

Read (*a*), and give a reason for the fact. Read the successive statements, and explain their meaning.

Make a statement defining the condition of the boun-

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dary system in the different ranks of plant life; make another, stating its office.

Since the boundary system of tissues is the first to be developed, it lies in a mass of thin-walled protoplasm, ready to be thickened and modified into the skin of the plant.

IV. **The boundary tissue system is the simplest and earliest result of plant growth.**

V. **It is divided into skin, hairs, and breathing-pores.**

Club Moss.

TEST.

ORAL.

1. Give the meaning of the words *boundary system.*

CAUTION. — *Remember that all tissues are pushed out from the growing points of plants, and that many circumstances combine to press and perfect boundary tissue to be the plant's glove.*

2. Examine stems and leaves, and give three qualities of boundary tissue.
3. Tell which cells of the plant become modified in this way.
4. What degree of change into boundary tissue is needed in the case of, —

a mullein leaf?	live-forever?	mildew?
a blade of grass?	fungus?	water mould?

WRITTEN.

1. Write two statements about the formation of boundary tissue.
2. Write a statement about its position in the plant.
3. Write three statements describing its position in different plants.
4. Write a statement about its use.
5. Write a statement about the boundary tissue of fungus.

Fill the blanks, in the following, with words that will complete statements about the boundary system: —

The —— —— does not exist in the youngest parts of plants.

—— —— with their growth.

—— protects the —— from the ——.

In plants of lower types it is made up of ——, ——, and —— cells.

Such cells are very like the —— mass.

They readily —— and —— for their office as —— ——.

Many low plants have absolutely no —— ——.

The —— —— of a rose leaf is a proof of plant development.

The higher the plant, the more thoroughly protective is its —— ——.

The atmosphere and protoplasm —— and —— boundary tissues.

Write a list of adjectives suitably descriptive of the boundary tissue system.*

THOROUGH REVIEW, WITH PRACTICE.

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* The teacher must examine the lists sharply, note errors, and make them the basis of a review.

C.

MORE ABOUT THE BOUNDARY SYSTEM.

The Skin.

THINGS TO REMEMBER.

A skin is made of cells modified by (1) change of form, (2) thickened walls, (3) loss of protoplasm. All these changes may be very slight.

Cells may change their form but not thicken their walls in, —

(1) large aquatic plants.
(2) land plants living in shade.

The cells thicken their walls without changing shape in, —

(1) land plants which grow very uniformly.
(2) plants bred in very dry air.

Thickening of cell-walls destroys protoplasm.

Skins of plants living in water or growing in damp earth retain some protoplasm.

1. Name the outer tissue of a cabbage leaf, and tell of what it is made. Name the tissue of another leaf made of the same.

Changes in the form of skin-cells is due to the mode of growth of the plant. If the plant grows alternately tall and broad, the cells are extended and flattened.

If the growth is mainly in one direction, the cells are not irregular; as in, —

grass blades, the leaf of Indian corn, the grains.

VI. **The true skin is one layer of cells.**

VII. **The outer part of the thickened cell-walls often separates into a continuous, safe wrap around this layer. This wrap is called the cuticle.**

For various reasons, the skin may split into many layers. This is true of the *oleander* and *cactus*.

Test I.

Make cross-sections of a cabbage leaf, and mount with care. Note the thickened cell-walls. The outer skin upon our bodies is very like the thickened and separable cuticle of the plant.

Mount and examine the skin upon a leaf of, —

oleander,	holly,	mullein,	petunia,
cactus,	milkweed,	verbena,	geranium.

Describe the material of the skin of each.

Test II.

1. Mention a plant skin that is made of, —
   - (*a*) regular cells.
   - (*b*) irregular cells.
   - (*c*) cells full of protoplasm.
   - (*d*) thin-walled cells.
   - (*e*) thick-walled cells.
   - (*f*) more than one layer of cell tissue.
2. How many of these names are of aquatic plants?

Test III.

Write five names of plants near your home.

Name their tissue system which you see and touch; its parts; its most important part; the composition of this part; decide whether its cells are regular in each plant.

Make three statements about (*a*) a cactus, (*b*) geranium, (*c*) kelp.

What is the boundary system? the skin?

Mount a bit of cactus. Treat the cuticle with iodine. It will turn yellow, and can be easily told from true skin.

Examine the *bloom* of fruits and leaves. Mount, and note that it is a waxy matter developed upon the cuticle.

D.

HAIRS.

Mount for examination, —

hairs of { petunias. / verbenas.

mullein hairs.

a root with root-hairs.

glandular hairs* in different stages of development.

VIII. **Hairs are extensions of the cells of the true skin.**

They at first protrude but little.

They lengthen, and sometimes become branched.

* Hairs secreting some substance.

Hairs are very important upon young roots, where they are called root-hairs. Their walls are so delicate that they absorb plant food.

Describe each mounted specimen, telling (*a*) the degree of cell extension, (*b*) if the hair is glandular, (*c*) whether it is simple or branched.

Give, from memory, three examples of root-hairs; three of variously branched hairs.

Think of a reason for the secretion furnished by glandular hairs.

Give an especial use of root-hairs.

Put upon the blackboard a statement of the material of skin-hairs.

Give in two statements, from mounted specimens, the progress of development of glandular hairs.

A root-hair is a single cell.

Place under the slide and describe the appearance of a hair upon, —

the root of a seedling maple.
a root of geranium.
a section of beet root.
roots of Indian corn.

Examine the entire root of an annual, and decide *upon what part* of the root the root-hairs are found. Are the old or fresh root-hairs most absorptive?

E.

BREATHING-PORES.

Our skin has been called the third lung, because we exhale and absorb by it. This is done by pores upon skin surfaces.

The presence of these pores is proved by accidents. If a certain proportion of them is destroyed by burns, scalds, or skin diseases, death results.

The plant has breathing pores, also. They are of importance to its life.

IX. **Breathing-pores are slits in the skin. The slits are guarded by special chlorophyll-stained cells.**

They are found upon aerial leaves and stems very abundantly; upon underground leaves and stems less abundantly; and upon true roots never.

Mount a cross-section of cabbage leaf. Look for breathing-pores. Examine leaves of the,—

red clover,	pea,	Indian corn,
sunflower,	thorn apple,	iris.

Which surface of the leaf possesses the most breathing-pores?

The lower surface.

Are there none upon the upper surface?

Breathing-pores are often confined to the lower.

1. Read the names of these leaves; find specimens, and tell whether they possess breathing-pores on both surfaces: —

black walnut,	cherry,	apple,
lilac,	hop,	plum,
sycamore,	lily,	box.

X. **Sometimes the chlorophyll cells shrink and curve away from the slit called a pore. The air then passes freely to the inner structures.**

2. Write five names of aerial leaves, and the surface on which breathing-pores are most numerous.
3. Use the term *breathing-pores* correctly in a statement containing (*a*) an aerial leaf, (*b*) an underground stem, (*c*) a root.
4. Write the name of a leaf which has breathing-pores upon both surfaces.
5. Write a statement defining a *breathing-pore*.
6. Write statements in which you use correctly, —

boundary system,	hairs,	pores,
chlorophyll cells,	skin,	tissue group,
	tissue system.	

CHAPTER IV.

THE SUPPORTING SYSTEM.

DIRECTIONS. — Break a stem of door-yard plantain, and note the tough strings of supporting tissue which run through the soft tissues. The bundles may be readily pulled out.

1. What is found in higher plants?

Portions of interior tissue lengthen into bundles which penetrate the other tissues.

2. What is the name of these strengthening bundles?

Supporting tissue.

3. Give its composition.

Fibrous and soft tissues.

CAUTION. — *The amount of soft tissue varies, and there is an admixture of less abundant tissues, of doubtful interest to primary classes.**

TEST I.

Describe the supporting system of the plantain leaf and stalk.

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* See page 14.

A. *In many plants, supporting tissues may be as readily separated as is that of the plantain. They are tough and strong, and divide quickly from more yielding portions of the plant body.*

B. *The leaf determines the supporting tissue, which is often left as a lace-like framework by beetles, caterpillars, and many grubs, who like the soft chlorophyll tissue which pads and fills out this little skeleton.*

C. *If you will notice about the framework of your hand or your foot, you will see that the leaf and the stem, and the parts of the flower, and the tissues of fruit, are strengthened and held in proper shape by supporting tissue, very much as the systems of tiny bones within your flesh keep your hand and foot from being limp and shapeless.*

Use these items in statements about supporting tissue: —

fibrous tissue, chlorophyll tissue, leaf, stem.

Study the bundles of asparagus. Write a statement defining their texture, and their use in the plant body. Study a section of corn stalk, and describe accurately the position of the supporting system of tissues. Note if it be tougher than in asparagus, and give a reason.

Examine the framework of a leaf, and tell (1) why the tissue branches so much, (2) why it is so firm and strong, (3) whether soft or fibrous tissue must be more abundant to give this toughness. Give the material of fibrous tissue.

Look over your written work and tell, —

(*a*) the chief materials of supporting tissue.

(*b*) where supporting tissue is found.
(*c*) its appearance in a plantain leaf.
(*d*) what usually pads supporting tissue.
(*e*) where it is found in the plant structure.

Test II.

1. Is the supporting system always as plain as in the plantain?

In many plants its limits are vague, and can hardly be told from the inside tissues.

2. Give the material of the supporting system.

From the central tissues is pushed a sheath of narrow, long, thin-walled cells. This develops a padding of soft tissue, and outside this padding appears a zone of fibrous tissue. Around all, a layer of starch-bearing cells is packed. This finishes the "bundle."

3. Study the stem of red clover, and point out, —

the zone of thin-walled cells.
the layer of soft tissue.
the fibrous tissue.
the outside sheath.

The young bundles found in the upper joints will be most interesting. Those of the lower joints will display very much fibrous tissue.

4. Write a statement about the "bundle" of supporting tissue in the stem of ground-pine, or of lycopodium.

Test III.

1. Name all the parts of a supporting tissue, and tell what part comes next to the boundary system.
2. What do the parts of the supporting system make?

I. **The supporting tissues form wood and bark.**

3. Turn to the stem of red clover, and state the position of each part of the supporting system. Do the same with the supporting tissues of plantain.
4. How does the bundle develop?

   First, from the simple protoplasm of the growing plant.
   Second, from the zone of long, thin-walled cells.
   Third, by the change of such cells into bundle tissues.
   Sometimes *all* these cells stiffen into permanent tissue. Such cannot grow further.

5. Of what use is this supporting system? Why is the material arranged so carefully?

Test IV.

BLACKBOARD.

1. Select two pupils to write the items of a "bundle."
2. Have the class tell the material of each item, and what they consider is its use. Teach that the laws of the plant's growth pack the tissues according to the needs of the plant body.
3. Receive criticisms and have corrections made.
4. Call attention to the veining of tree leaves, of some plucked-off shrubs, of a leaf of geranium, of a petal.

Have the class tell the material of the veins, and their true name. *Review* what a "bundle" is, where it is found, when, where, and why it is tough and easily drawn from the other systems.

5. Blackboard practice in writing statements about, —

the use of the supporting system of tissues.
its position in the plant body.
its make-up.
its appearance in the plantain stalk.
the supporting tissue of a geranium leaf.
the supporting system of trees and shrubs.

CHAPTER V.

THE FUNDAMENTAL SYSTEM.

A.

MATERIALS.

What have you learned about the tissues of a stem?

I. **The boundary and supporting tissues guard and shape a stem.**

Give examples.

II. **If they are stripped off, fundamental tissue remains.**

III. In the lowest and simplest plants everything inside the skin belongs to the fundamental system; as, —

a kelp, rock weed, most mosses.

IV. **In the stems of large trees there is very little fundamental tissue present.**

Point out the fundamental tissue in the following, and think about what its use must be: —

a cross-section of pumpkin stem.
a section of milkweed.
a slice of young wood.

How is the fundamental system told in wood?

V. **The pith of trees, and the rays which run through wood and bark, are made of the fundamental system.**

In wood this system is nearly crowded out by the development of boundary and supporting tissue.

(1) Tell of what each of these words is the name,—

soft, fibrous, stony, milk.

(2) Describe soft tissue.
(3) Give an example of fibrous tissue.
(4) State the condition of walls of stony tissue.
(5) Name the colored fluid of milk tissue. In how many forms does fundamental tissue develop?

VI. **The fundamental system may hold soft, stony, fibrous, and milk tissues.**

Write the names of the tissues found in the fundamental system of, —

pumpkin, squash, milkweed, apple twig.

Exercise.

1. Write the name of the tissue which is most abundant in, —

   kelp, cactus, fleshy leaves, fruits.

2. Examine mounted specimens of the above, and state the position of this tissue in the fundamental system of each.
3. Collect five common specimens, and carefully note the amount of soft tissue in comparison with the three others, and where it is found.

VII. **Soft tissue is the most abundant of the fundamental tissues. It is usually the central tissue mass.**

1. Look for fibrous tissue masses near the skin in the following: —

leaves of Scotch pine, ferns.

VIII. **Fibrous tissue in the fundamental system forms band-like masses, giving strength to the plant form.**

2. Locate fibrous tissue in the fundamental part of, —

the leaf of Scotch pine, moss stems,
the fern stems, fern leaves,
the leaf of a flowering plant.

Milk tissue is found in any part of the fundamental system of flowering plants.

We see that the tissue masses of the fundamental system are so arranged that the boundary is firm and the interior soft. So we find that the simplest system can develop what is needed for life. The fibrous and stony tissues lie on the outside of the mass of soft tissue.

B.

SPACES BETWEEN CELLS.

Where are spaces between cells found?

Upon leaves, leaf stalks, and stems.

In what leaf surface are they usual?

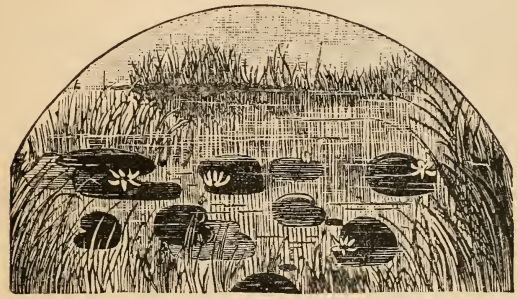
In the soft tissue of the under surface.

What do they hold?

Air and vapor.

Where are the spaces large enough to be seen without a glass?

In the rushes and water lilies.



Water Lilies.

Examine cross-sections carefully, and state three properties of these large spaces.

They are shaped like canals, conduct air, and communicate with the breathing-pores.

Where are the spaces found in water plants?

Usually upon the upper surfaces of leaves and leaf stalks.

Give a reason.

The lower surfaces of leaves which float on the water have few breathing-pores. Stalks entirely under water have few pores.

How are spaces between cells formed?

By the rapid growth of cells of soft tissue.

What is their size and shape in most plants?

Usually small and irregular.

What do they much resemble?

Cells.

Where are they largest?

In water plants, the pine tree, and some fruit rinds.

What are some intercellular spaces?

Wells of gum.

Such spaces are walled in by cells making the gum and exuding it into the cavity.

Name a product secreted in this way.

Turpentine.

1. Study turpentine canals in the large-leaved pines and spruces, and note —

   shape, size, boundaries,
   character of the boundary cells.

2. On which surface of the leaf do they prevail?
3. Study cross-sections of the leaves of, —

   spearmint, bergamot, sage.

   Describe the oil receptacles.
4. Describe the turpentine canals found in slices of the stems of, —

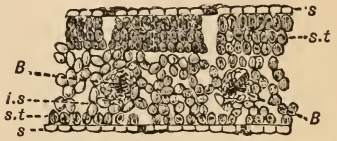
   scrub pine, white pine, balsam fir.

Exercise I.

Find the spaces between cells in, —

the soft tissue of pith.
the leaf stalk of a water lily.
a stem of ivy.

Write statements about the size, shape, and contents of the spaces found in each. Cross-sections must be used for mounting.



Section Through Leaf.

s. skin.
s.t. soft tissue.
i.s. spaces between cells.
B. bundles.

Exercise II.

Define the word *intercellular*.

A. Tell whether the intercellular spaces of this list are (*a*) slight or well developed; (*b*) whether they contain air, or gum, or oil: —

fresh lemon rind.
leaf stalks of water plants.
the rind of a fresh orange.
the lower surface of an apple leaf.
geranium leaves.
a leaf of the black currant.
meadow grass.
a stalk of ice plant.
leaves of sundew.
stems of the moss rose.

B. Make a statement about spaces upon, —

a leaf of the passion flower.
moss rose buds.

c. Fill the blanks in these statements with correctly chosen words: —

(1) The fragrance of new hay is caused by —— in the —— of meadow grass.

(2) As the tissues of the grass blades wither, the —— exudes to the surfaces.

(3) The intercellular —— of pine leaves are —— and contain ——.

(4) Spaces between the cells of —— plants are found upon upper sides only.

(5) The —— spaces of ice plants are wells of —— which looks like ice.

(6) The —— surface of an apple leaf has no ——, because this surface is without —— ——.

(7) Study the —— —— in the fresh rind of the orange and lemon.

(8) Make cross-sections of the —— of white pine, and study —— —— in bark and wood.

Review.

ORAL.

Read these words: *boundary*, *supporting*, *fundamental*.

Use each of them in connection with *plant tissues*, and tell how and why *tissues* divide into *systems*.

Define a *tissue system*. Where do tissue systems reach the fullest development? What plants are without them?

Name the three modifications of cells of soft tissue to form the *boundary* system. Define —

change of form.
thickening of walls.
disappearance of protoplasm.

Account for changes of *cell form*, and for thickening of *cell-walls*.

Locate *skin*, *hairs*, and *breathing-pores* in the boundary system of higher plants. Is the system separable in the *lowest* plants? How separable in *higher fungi?* When does *protoplasm* disappear rapidly in *skin*-cells? When slowly? Give examples. How many *layers of cells* in the *skin?* An exception.

Are the cell-walls of skin tissue thick or thin in, —

kelp? blights? clover? lily leaves? leaf of holly?

Account for the *bloom* upon a cabbage leaf.

What are *hairs?*

Ans. They are absorptive cells piled upon each other.

Describe their growth. Tell the most important hairs. What is the use of *root-hairs?* Give one example of *simple* hairs. Of greatly branched hairs.

What do the hairs of these plants manufacture? —

Chinese primrose, petunia, verbena.

Describe breathing-pores upon, —

aerial leaves,	lower leaf surfaces,
submerged stems,	a lilac leaf,
true roots,	lily leaves,
red clover,	a petal.

Find the *supporting system* in, —

(*a*) plantain,	(*d*) red clover,
(*b*) Indian corn,	(*e*) castor-oil plant,
(*c*) sweet flag,	(*f*) brake fern.

Of what is the supporting system made up? Why is it needed, and how do the tissues draw together to form the "bundle"?

What is the *fundamental system?* Name the four tissues found in it.

Tell where in the fundamental system you will find these tissue masses: —

soft tissue,	stony tissue,
fibrous tissue,	milk tissue.

Name the composition of a verbena stem, and tell in statements the use of each system of tissues.

Define *intercellular.* Describe *intercellular spaces.* Define a turpentine canal.

BLACKBOARD.

Write, and use correctly in written statements, —

1. The names of tissues of plants in the schoolroom.
2. The names of tissues of five plants seen on your way to school.
3. The names of tissue systems in plants at home.
4. The name of a plant which possesses root-hairs.
5. The name of a leaf which has breathing-pores on its lower side only.
6. The name of a plant which has no skin.
7. The names of plants possessing supporting systems of tissue.
8. Four words that are the names of masses which form the fundamental system.

9. The name of a plant having, —

a branching hair,	a tough "bundle,"
a hair which is a gland,	"bloom,"
very much soft tissue,	a gum reservoir,
stony tissue,	an oil receptacle.

10. The tissues of plants mentioned in a lesson of your Reader, or in an article of a newspaper, or on a page of a book.

ORAL AND BLACKBOARD.

Write a definition of protoplasm, and the plant cell.
Write your idea of a plant tissue.
Give, in written statements, —

(*a*) the name of a plant body whose tissues have developed into tissue systems.
(*b*) the name of another, which is a single cell.

Copy this sentence: —

"The cells, tissues, and tissue systems are arranged to form the *plant body*."

Carefully explain how, —

(*a*) cells are pressed into tissues.
(*b*) tissues divide into systems.

Give the name of the system which (1) conducts, (2) supports, (3) guards.
Of what are all these tissues made?
Where are they lying undeveloped?
Name a plant wholly of naked protoplasm.

CHAPTER VI.

THE PHYSIOLOGY OF PLANTS.

A.

WATER IN THE PLANT.

DIRECTIONS. — "Weigh a handful of green grass; dry it in an oven. Weigh again: the difference in the two weighings will be very nearly the amount of water in the living plant."

1. Name the living part of every plant.
2. Dictate the following for class use: —

Water is always present in living protoplasm; and the greater its activity, the more watery is its composition.

3. What does the water in protoplasm hold? A proof.*
4. Why is more water required, according to the activity of protoplasm? Write a statement concerning tissues developed by this activity.
5. Write another statement, naming points in the plant where water is especially needed.

The cell-walls of living tissues contain much water.

6. At what points of the plant will cell-walls be thus saturated? Why necessarily so?

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* Plants die without it.

7. As tissues develop and stiffen into shape, is the water wholly lost?
8. Prove this by common specimens of flowering plants.

Water is so abundant in very simple aquatic plants, that upon drying them a mere film is left.*

9. What percentage of water has a growing land plant?

The amount of water in a higher flowering plant is seventy-five per cent of its weight.

The amount of water in seaweeds is often ninety-five per cent.

10. Read the statements of the lesson. Mention the items in each about water in the plant body. Tell which great class of plants contains most water, and why.
11. Why is water so plentiful in active protoplasm?

1. Write a statement about water in the following plants, and give the percentage as *low* or *high* of water in the plant body: —

   (*a*) green slime, kelp.
   (*b*) a verbena, grasses.
   (*c*) mosses, ferns.

2. Read the statement, and give very clearly the percentages of water.
3. Tell what is found in protoplasm, and what saturates cell-walls.
4. Mention the parts of the plant where watery protoplasm is most abundant. Give a reason.

---

* Explain to the class the meaning of the word *aquatic*.

5. Review the dictated sentences. What have you learned about water in plants?

I. **All living parts of the plant are abundantly supplied with water.**

All parts of the plant body, except old wood, are living parts.

B.

WATER IN PROTOPLASM AND IN CELL-WALLS.

Living protoplasm absorbs water for the sake of the food which the water holds. This swells the protoplasm, and is a cause of plant growth. When protoplasm has absorbed all the water it can hold, it continues the process and distils the drops of water within its own boundaries, as reserve matter.

The cells of growing tissues display very watery protoplasm. Those of living but sleeping tissues hold thick, jelly-like protoplasm; thus, —

Put dry beans in soak: the first sign of life is the absorption of water.

Seeds are buried in earth so that they shall absorb the moisture of the soil. A dahlia bulb is soaked, in order to wake the protoplasm in the tissues.

A seed which will not sprout in water has no living protoplasm.

Water in protoplasmic cells keeps them full and shapely. By this general bracing force soft tissue is kept rigid, and the plant is assisted to its shape.

Verify the rules by examining with the microscope well-soaked beans that are beginning to sprout. The absorbed water will be very visible, and its value at the growing point seen in detail.

Or, make cross-sections of the tips of the roots of Indian corn, or sections of young asparagus shoots. Examine with the microscope. Stain them with iodine. The protoplasm will turn brown. Note the drops of water inside its substance.

1. What is a cell?
2. Of what is green slime made? The oak? The elm?
3. State the grand point of difference between the slime and elm.

   Ans. *They differ in the number of cells employed.*

4. What is a cell-wall?
5. Read carefully this description of its structure: —

(*a*) *When you look at a slant sunbeam, you see a layer of dust atoms, among which the air appears to be freely passing.*

(*b*) *A cell-wall is a layer of solid particles not in contact, between which the water freely passes.*

(*c*) *Cell-walls thicken into formed and perfected tissues by the great increase of solid particles. Solid particles are used-up matters, thus laid on a shelf.*

Task.

In aquatic plants of low orders the flow of water is continuous from the outside to the inside of their structures. Mount pieces of kelp or fresh-water plants, and note the wateriness of cell-walls and contents.

By the specimens examined, write statements about,—

(*a*) the composition of the growing point of a plant, its wateriness, and two reasons for this saturation.

(*b*) the proof by actual weight of the absorption of water. Its help in supplying the waste by evaporation.

(*c*) the continuity * of water in tissues with that of the soil. The flow in aquatic plants. Describe the real formation of a cell-wall.

Caution. — Look over your paper, and see, —

that all your groups of words are statements.
that no word is omitted or misspelled.
that the word *protoplasm* is always correctly used.
that you understand what you are expected to know.

Varied and persistent practice with specimens.

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* This word seems the indispensable thing, but had best be explained with an illustration.

C.

DISTURBANCE OF WATER IN THE PLANT.

II. **In winter the water in a plant is motionless, and the plant body rests.**

During the warm months plants grow, and the water in their structures is disturbed (*a*) by actual breakage into gases for the plant's use; (*b*) by displacement by solid material manufactured in the cell; (*c*) by displacement by liquid matters manufactured in the cell, as, —

The gradual formation of the tissues which lie undeveloped in the growing points of the plant.

III. **This work goes on in all cells of all plants, proving that a simple yeast cell is as truly a plant as is a rose tree.**

If a tiny drop of water is broken up into gases, what is left?

Every drop thus broken up leaves a vacancy.

How is the vacancy filled?

It is filled, sooner or later, from the flow of water in the cell.

TASK.

Give the reason of the winter rest of plants.
Describe the condition of the water in a plant body during the cold months.
How is water a plant material?
Give two disturbing agencies in a cell.

As the drops are used by the cell protoplasm, how are vacancies filled?

From what cells are supplies drawn?

ANS. **New supplies of water are drawn from the nearest cells.**

CAUTION. In aquatic plants of low orders the needed water is absorbed directly from the surrounding water. Higher aquatic plants possess systems of tissues. In this case the deep-lying tissues must draw their water supply from surrounding cells.

Dictate statements concerning water at rest and in motion in, —

(1) an oak.
(2) a bit of kelp.
(3) a grown geranium.
(4) a bean sprout.
(5) specimens of green slime or of pond scum.

IV. **All parts of plants above the ground or above the water depend entirely upon cell supplies of moisture**; as, —

All the growing cells of the flowering plants and weeds which we have about us in summer.

All pad-like leaves that rest upon water surfaces, and all the blossoms of such plants.

All *aerial* (*living in the air*) roots and rootlets.

Give with care, the route of a particle of water from the soil, at the root-hairs of a geranium, to the growing points of the plant body.

The route of a like particle from the outside to the centre of a well-grown water-lily plant.

Examine slime or scum, and describe the absorption of water.

D.

EVAPORATION.

1. What is a disturbing element in aerial parts of plants?

V. **Evaporation of water in the aerial parts of plants is a powerful element of disturbance;** as, —

Expose a cell of pond scum to dry air; the evaporation is seen by the collapse of the cell.

VI. **Evaporation of water in one cell disturbs the water throughout the tissue, and compels it to re-adjust itself.**

VII. **Dry air and light have influence upon evaporation. If the air is full of moisture, the water in the plant body cannot exhale, and the cells are distended. When the moisture is blown off by the wind or is dried up by the sun, evaporation begins.**

2. Note and express in statements the relative rapidity of exhalation in the following experiments: —

Fresh leaves of clover suspended in a tumbler which stands on a wet plate.

Other fresh leaves in a dry plate, with no protection from dry air.

3. What retards evaporation?

VIII. **The thick outer layer of skin-cells in the higher plants resists the escape of water.**

The simple cells of the lowest plants are guarded by very thick walls; as, tough moulds.

TEST.

WRITTEN.

Write the relative rapidity of evaporation in the case of, —

the garden plants on a wet day.
a cactus.
geranium leaves during the night.
green slime upon a damp wall.
the same placed in warm, dry air.

ORAL.

What parts of plants are exposed to evaporation? How does it disturb the water in the plant? When is this disturbance greatest?

ANS. *When evaporation is most rapid.*

How many, and what conditions favor evaporation? What influence has heat?

The absorbing power of protoplasm is a "slowing" power about evaporation.

Give another reason why plant evaporation seems slow.

ANS. Cell water holds many more matters in solution than does pure water, by whose evaporation we are apt to judge it.

Why has a cactus a thick skin? In what climates will many layers of skin develop upon a stem?

How are plants that are single cells protected?

Define breathing-pores. Locate them in the boundary system. What do breathing-pores greatly control?

ANS. The rapidity of evaporation.

What fills intercellular spaces? How do the spaces communicate with outside air?

ANS. By the breathing-pores.

Is exhalation from the spaces between cells constant? What stops the flow of moist air from these spaces?

ANS. The closure of the breathing-pores.

Upon what does the opening and closing of breathing-pores depend?

ANS. Upon the surface of the boundary system and upon light. When the plant skin is very dry, they close.

E.

MOVEMENT OF WATER IN THE PLANT.

Why is a movement of the water of the plant unavoidable?

A considerable movement of water supplies the loss by evaporation.

(*a*) **In the trees and shrubs we live among, the movement of water is upward to the leaves. Leaves are losing water continually.**

(1)

Cut off a tender stem at noon of a dry day; the leaves wilt at once.

Place the cut stem in a tumbler of water.

Water is greedily absorbed by the stem, and the leaves regain freshness.

(2)

Tinge with carmine ink the water in the tumbler. Let the stem be delicately thin. In a few minutes the liquid will stain some tissues deeply, and others very slightly. Name the tissues which conduct the fluid easily.

(3)

Place a leafy apple twig in a bottle of water. Close the mouth with wax to prevent any evaporation from the water surface. The level in the bottle will perceptibly lower, proving the loss by evaporation.

(4)

Your own experience with a bouquet of cut flowers.

(*b*) **The tissue masses through which water usually passes rapidly are those formed of tube-shaped cells of woody material.** (See cut specimens with the glass.)

(*c*) **The movement of the water is through the cell-walls more than through the cells of the tissue masses just described. Solid particles of cell-wall attract the water in which they float, and thus, by different displacements, it rises to the top of tall trees.**

(*d*) **Water moves upward rapidly or otherwise, according to the plant. It has risen nine inches in an hour in a silver poplar.**

Bring a little branch of sugar maple into a warm schoolroom. As the branch warms, the sap will flow from the wound. Put it out of doors a few minutes, and the flow will decrease; bring it in again, and the sap will drip as before. This must be done on a cold day — say zero Fahrenheit or thereabouts.

What have you learned about the flow of water (sap) from sugar maples?

(*e*) **The flow of sap from the stems of sugar maples seems due to the influence of heat and cold upon the tissues of their boundary systems. The water is forced out when it is warm; at night, when it grows cold, air is drawn into the stem. When the temperature is much alike through the twenty-four hours, — that is, in hot weather, or in very cold weather, — there is no flow of sap.**

Is there a "circulation of sap"?

(*f*) **There is an upward movement of water, through the warm months, in order to supply the loss from the leaves. There is no downward movement to correspond. "Circulation of sap" does not exist.**

Remember, —

(1) *that water does not* go down into the roots *of a tree in the autumn, nor* rise *in the spring.*

(2) *that there is more water* (sap) *in an ordinary tree in winter than there is in the spring or the summer.*

(3) *that the reason of this abundance is the loss of the leaves, the agents of evaporation.*

Test I.

Use these items in a statement: —

Reason of the movement of water in plants.
Direction of the movement.

Write an example of the route of water up the trunk of a tree.

Write the formation of the preferred tissue masses of the route, with a reason why continuous woody cells can draw water drops to the tops of tall trees.

Write a statement about the so-called circulation of sap, and mention a popular error about the location of sap in winter.

Look over the statements written, and tell, —

(1) why the water must be in motion throughout a growing plant body.
(2) why its route is upward.
(3) how this may be easily proven.
(4) what tissues it prefers for its path.
(5) whether there is sap in perennial plants "the year around."

Perennial plants — roses, currant shrubs, etc. — live above ground through the cold months. Annuals — like the phlox and the pansy — die to the ground in early winter.

Test II.

How would you begin a composition about "The Movement of Water in Higher, or Many-Celled Plants"? Think of a proper arrangement of items.

Describe, —

(*a*) a many-celled plant.
(*b*) evaporation.
(*c*) breathing-pores.
(*d*) cell-walls.
(*e*) roots.
(*f*) stems.
(*g*) branches.
(*h*) leaves.

Write the composition.

Tell whether there is a movement of water in single-celled plants; if it is considerable. Mention one reason for your decision.

CHAPTER VII.

MORE ABOUT THE PHYSIOLOGY OF PLANTS.

A.

PLANT FOOD.

What is plant food?

I. **Certain gases and matters which you will by and by find named and explained in chemistry.**

Sea Weeds.

Some of these matters are essential to our own living; as, sulphur, iron, and oxygen.

With the exception of oxygen, these elements become mixed before the plant uses them. They are usually also mixed with water. No plant can get on without water.

CAUTION.—*Some plants live upon the juices of host plants, as the* mistletoe; *many more live upon decaying matters of the soil, or upon decaying animal matter, as the* Venus's fly-trap.

How is the food eaten?

II. **The tissue masses of water plants are so perfectly saturated by the surrounding water that the food matters which it holds are taken easily into the plant body.**

III. **Leaves of land plants are steeped in the surrounding air, and take from it gases which are plant food.**

IV. **A watery abundance of these foods and all other necessary things to eat are absorbed by the root-hairs of land plants.**

V. **The water of the soil holds food materials of all sorts, furnishing them to plants in tiny quantities, and going with them inside the plant body.**

TEST I.

BLACKBOARD.

Write a statement about plant food, mentioning one food common to the animal and plant worlds.

Copy the following names of plants, and use them correctly in statements, locating them as land or water plants:

pond lily,	primrose,	toadstools,
begonia,	plantain,	smuts,
geranium,	grasses,	rusts,
sundew,	cat-tail flag,	ferns,
Jack in the pulpit,	duckweeds,	red seaweed,
mosses,	puff balls,	lichens,
		pitcher plants.

Decide whether each takes food from (*a*) surrounding waves, (*b*) air and soil water, (*c*) other plants, (*d*) dead animals.

Rewrite your work, making from it one correct and full statement about each plant.

Name the strange plants of the list.

CAUTION. — *The puff balls and toadstools which we see are fruits. Their plants live underground in any soil full of decaying vegetable matter. Lichens live upon little host plants.*

Write a statement about the food, and habit of eating, of three plants found in your neighborhood.

CAUTIONS. — (1) *Do not leave out the item of location; that is, whether they are* water *or* land *plants.* (2) *Name the few food materials you know.* (3) *Always name one food material necessary to plants and animals.*

TEST II.

ORAL AND WRITTEN.

1. Tell of what two classes all plants must be.
2. Name all the methods of obtaining plant food. Give the most common methods. Write an example of each.
3. Which holds the most plant food, well water or pond water?
4. Dictate the name of a plant, —

   (*a*) which takes food directly from the water in which it lies, and spends its whole existence.

(*b*) which has many leaves spread in the air, a stem with many breathing-pores, and many rootlets penetrating the earth.

5. Use these items in statements: —

(*a*) Blue mould; air; decaying tissue; land plant; old pastry.
(*b*) Ferns; air; soil water; land plant.
(*c*) Slimes; water; food supply; water plant; oxygen.

B.

HOW THE FOOD CIRCULATES IN A PLANT.

What does the word *food material* mean?
Do the foods circulate in solid parts or watery parts of plants?
Name two food materials.
Name two methods of absorption.

ANS. Absorption directly from surrounding air or water, and indirect absorption by diffusion from rootlets.

Do *aerial* parts absorb gases or watery foods? What aerial members of the plant body absorb gases?
How would a perfect state of rest throughout the plant body promote an equal diffusion of food?
What aids the diffusion of food matters?

(*a*) Evaporation greatly aids transportation of food materials by a strong upward movement of water.

(*b*) The water drawn upward to the leaves holds in its surfaces the plant foods, and leaves them along its way for the plant's benefit.

(*c*) Plant food can be diffused through plant tissues without any dependence upon evaporation, although it is usually carried along in the water in its upward route.

Tell what process aids transportation of plant food.

How is movement of the water in the tissue masses promoted by evaporation?

Can diffusion of plant food progress without it? How?

ANS. By the constant changes of position of the protoplasmic particles composing a growing plant.

Adder's Tongue Fern.

EXERCISE I.

Sprout three kernels of corn, and transfer them to jars full respectively of distilled water, well water, and pond water, and tell, —

(*a*) whether the plants grow in all the jars.

(*b*) what very important food is in all the jars.

(*c*) in which jar the plant does best.

(*d*) how the food materials are scattered through the plant body in each jar, and what process aids the diffusion.

What hinders an equal diffusion of food throughout the plant tissues?

ANS. Chemical changes that happen as soon as food touches tissue hinder an *equal diffusion* of food matters.

EXERCISE II.

1. Try a simple experiment with plant foods, and state results from plant growth.
2. Write a reason why pond or river water is a tonic for plant life.
3. Name a food material absorbed from the air.
4. Mention one reason for the unequal transportation of most foods among tissue masses.

   ANS. Unequal extensions of the plant body by growth.
5. Write in statements a description of internal changes, with the reason why they are inevitable in a certain order of plants. Name the order.

   ANS. *The higher order.*

EXERCISE III.

(Just before the hour is up.)

Correct all mistakes made in Exercise II. Place the correct statements on the blackboard.

C.

STARCH.

1. By what is food material used?

Food material is used by the protoplasm, and generally at once; thus, —

Water is at once made use of.

2. What has to be done with the food for the green parts of plants?

It has to be broken up and worked over inside the plant body.

3. What is the new food material called?

It is starch; and the working over is called starch-making. Starch-making goes on in chlorophyll grains in all the green parts of plants.

4. *Oil, instead of starch, is manufactured in the chlorophyll grains of certain plants.*
5. Spell and define *chlorophyll, chlorophyll grain.*

What is necessary for starch-making?

Sunlight and chlorophyll masses are necessary for starch-making. Parts of plants devoid of chlorophyll make no starch, and chlorophyll masses are unable to manufacture starch in darkness.

What is done during the dark hours?

The new food material — that is, starch — is digested, and transported to all parts of the plant body.

Starch is changed during digestion to liquid matters, in order that it may thus rise very easily in the tissues. Cane sugar is one of the watery forms of starch.

How Foods are Stored.

Write a statement about the potato.

How is a potato filled with starch?

The potato leaves make starch in sunlight. In the night starch is changed to a liquid food, and is sent throughout the plant stems. In the underground stem (potato) *the liquid food turns to starch again.*

Why is starch stored in the potato?

Describe a starch cupboard that is not an underground cell.

Tell what the castor bean stores.

Why is any sort of food material reserved in stems or seeds?

What will they sometimes feed?

At what time will they be needed?

Name and describe the making of an important food stored by, —

(*a*) the artichoke, with particular mention of the points of the plant where the material is first manufactured, and of a change which takes place afterwards to aid diffusion.

(*b*) kernels of green corn. Taste them, and name the material which tastes sweet. Is this *starch* or *liquid food?*

(*c*) a mustard seed; tell a use of the plant food stored in it, and why the seed is a good cupboard.

(*d*) flaxseed.
(*e*) some plant with which you are familiar.

Name parts of plants which cannot make starch or oily matters.

Give a reason for such failure; tell the case of leaves and similar plant organs in darkness.

Write a statement about the way plants store foods, and name two plants which store them in different tissue masses.

D.

USE OF RESERVE MATERIALS.

1. Copy the following statement: —

The sweet taste of kernels of growing corn shows that the starch has changed into sugar.

(*a*) What taste has a kernel of green corn? What does the second part of the statement show?

(*b*) Which words name food materials? Define the word *starch* in the statement.

(*c*) Explain what is meant by the word *sugar*.

Starch is changed into sugar for the nourishment of growing plants.

2. In each of the following, mention the change which has taken place, and mark the words that made you aware of it: —

The sugar beet is eaten.
The piece of cane is sweet.

The bud has a sweet taste.
There is sugar in an onion.

3. In the following, fill the blanks with words that show why starch is changed to sugar: —

Starchy seeds feed —— with ——.
Starch is too —— to penetrate —— masses.
Watery —— diffuse throughout the ——.
The sweet —— of maple —— shows the presence of —— changed to ——.

When reserve material is used, the starch suffers a change exactly like that upon leaving chlorophyll grains. It becomes a fluid food again.

Exercise I.

Use in sentences, —

starch,	squash seed,	buds,
sugar,	potato,	twigs,
oil,	chlorophyll grains,	bulbs.

Observe the qualities of underground stems, bulbs, roots, and fruits which you see at home, and try to rightly express the food materials which they store, and how the plants break up their reserve foods before making use of them.

Exercise II.

Use words that denote plant foods, as *starchy substances*, *sugary substances*, *watery substances*, in statements which show whence these foods are drawn, where manufactured, and whether stored in a solid or watery state.

CAUTIONS.—1. *All parts of plants may digest starch, store reserve material, and use food matters for their tissues;* as, the root eats; pond scum grown in the dark digests food; a flower petal uses food material.

2. *Starch-making goes on in the green parts of plants only; much starch is made in the leaves; no starch is produced by flowers.*

3. *Parts of plants which are not green do exactly like chlorophyll-bearing parts in the darkness; that is, they digest what food they can obtain. But you see how dependent they are upon the green organs.*

EXERCISE III.

(With the Teacher.)

☞ The teacher may vary the tasks by a familiar talk, or by some simple puzzle play about plants. The following method, adapted from a text-book upon another subject, is a very good one.

A. Each of you think of a cupboard of reserved plant food, of its taste or its quality. Do not tell any one what it is. As you name its taste (or use words which express its size or appearance or other qualities), I will write the words, and the class may see how many can guess the name of the cupboard.

B. When the pupil called upon has finished describing the object, refer to the items on the board, and ask, Who can guess what it is that "grows underground"; "may be big or little"; "is full of starch and is good to eat"; that is "small and hard and shiny"; "holds very much oil"; "is not nice to taste or handle"; "is very small"; "bread is made of it"? When the cupboard has been named, refer to the board and verify or correct.

c. Refer to the words and describe the plants to which they belong. Review the tissues of which the plants are made.

E.

TEMPERATURE.

A lowest temperature.
A highest temperature.
A best temperature.

There are three temperatures which should be studied for every plant; namely, lowest, best, highest. Plants can live only between the lowest and highest temperatures.

1. What is the highest plant temperature?

The temperature beyond which activity ceases.

2. What is the best temperature?

The temperature at which the plant thrives perfectly.

3. What is the lowest temperature?

That below which activity ceases.

4. Tell the effect upon house plants of the temperature of, —

a January day,	boiling water,
a hot oven,	a cold March wind.

The lowest temperature for plants is from the freezing point of water to 60° *above it. Some plants live at a*

lower temperature than others. The temperature varies, too, for the different parts of the plant; thus, a root will live at a lower temperature than a leaf.

The highest temperature for plants is from 95° *to* 120°, *varying for different plants, and for different parts of the same plant.*

5. Measure the temperature and describe the plant life of pond water in spring, when water plants begin to grow; of cold springs in which plants are found.

6. Notice in the newspaper the average daily temperature while tree buds are opening in the spring. Compare it with the average daily temperature during the ripening of the fruit.

The best temperature varies more than the lowest or the highest. Some plants pass their lives in air but little above the freezing point; thus, —

The red snow plant often covers the snow in higher latitudes.

It grows on mountain summits in low latitudes.

7. Plant in two pots seeds of barley or Indian corn. Leave one pot in a cold cellar, and put the other in a warmed room. To find the best temperature, compare the growth of the plants in the two pots.

8. Why are the leaves of trailing arbutus stiff, homely, and unattractive?

9. What reduces early water plants to a brown scum on water, or to a brown coat on stones?

The best temperature for land plants varies just as in the case of the lowest and highest. The best temperature for roots is lower than that for the plant above ground, and the best temperature for stems and leaves is lower than that for fruits.

10. Mention two plants that need, —

a very high temperature.
a very low temperature.
a middling temperature.

11. Name a plant which outlives early autumn frosts. What does its extended life prove about its best temperature?

Test Exercise.

What have you learned about the temperatures of plants? Apply the three temperatures in statements which show how vitally they affect plant life.

The Death of a Plant.

What happens when the temperature falls below a certain point?

Ans. **The plant dies.**

Explain its death.

A plant dies when the substance of the protoplasm stiffens. Loss of power to absorb water results, and the cell-walls lose shape, and collapse.

The tissues of watery plants and of most fleshy ones suffer most quickly in extremes of temperature.

Underline the names of leaves and stems which feel the first frosts keenly: —

a squash leaf,	an apple leaf,
a potato stem,	rose geraniums,
leaves of the butternut,	violets.

The results beyond the limits of the highest temperature are exactly like those produced by too cold air. Either result is a species of burn. In either case, watery cells are the first injured.

NOTES. — (*a*) **Plants asleep in dry seeds can be kept in almost any degree of low temperature; but when they break their tight blanket and sprout, the tissues of the sprout absorb much water, and the plant dies in a temperature lower than about 30° above the freezing point.**

Sprout beans or peas, and prove this by experiment.

(*b*) **The boundary systems of the ripened parts of native trees and shrubs usually endure extremely cold weather; but —**

The young shoots and tender leaves of large trees and shrubs are easily killed by spring frosts; as, —

the developing horse-chestnut bud.
any bursting winter bud.

Tell what temperature, medium, low or high, is the *best* temperature for these plants: —

red seaweed,	the apple tree,	magnolias,
kelp,	a cactus,	edelweiss,
moulds,	a prickly pear plant,	life everlasting.

Which of the above possess boundary systems suited to northern winters?

Which of the above would be most quickly affected by extreme temperatures; *i.e.*, temperatures beyond the highest or lowest limits which bound the plant's activity? If the plants are watery, give a special reason for their sensitiveness.

Chemical changes begin at once, as soon as extreme cold or heat touches watery cells. The tissues lose form very rapidly.

Write statements describing the apparent best temperature for three plants at home, or in the school yard, or in a park.

THINGS TO REMEMBER. — 1. *That a plant freezes because the water in the cell-walls and in the protoplasm turns to icicles. You have been taught that this water is not pure, but holds many plant foods. It will bear a lower temperature than will pure water. Very rarely is any plant completely frozen.*

2. *Many frozen plants will survive if thawed slowly. Many fleshy tissues (fruits) are not injured by freezing, but by rapid thawing. Thaw frozen apples in ice-water.*

TESTS.

(1)

1. Mention a temperature, and name three plants whose *best temperature* it appears to be.
2. Change the temperature so that it will show (*a*) the lowest temperature for the plants named; (*b*) the highest temperature for their activity.

(2)

Illustrate how the best temperature varies for roots, leaves, and flowers of the same plant; how it varies for—

two water plants.
two land plants.

Locate the plants given as examples. Give your idea of their lowest and highest temperatures, judging from the climates in which they are found.

(3)

1. Define the words *lowest*, *best*, and *highest temperatures*.
2. Copy from a book or newspaper the names of five plants.
3. Study their location and habits, and write after each what you think may be their lowest, best, and highest temperatures.
4. Describe variations of lowest and highest temperatures, and name, —
   (*a*) that part of the plant which will bear a lower temperature than other parts.
   (*b*) that part of the plant which requires a higher temperature than other parts.
5. What is the lowest temperature for all plants?
6. What is the highest temperature for plant activity?

(4)

Describe the death of a plant.
Why do watery tissues suffer quickly?
Mention similar results from widely different conditions.

In what cases will plants endure very low temperatures? Describe plant life in, —

a seed, winter bud, tree trunk or branch.

Why do few plants freeze solidly? Describe the condition of the water in their tissues. Tell how to preserve, —

a chilled shrub.
a frozen cabbage.
a frost-bitten apple.

CHAPTER VIII.

MORE PHYSIOLOGY OF PLANTS.

A.

LIGHT.

1. Read the following: —

   (1) House plants turn toward the light.
   (2) Moulds grow without the aid of light.
   (3) Fruits and flowers can develop in darkness.
   (4) Green plants directly depend upon light.
   (5) Light helps them to make starch.
   (6) Without starch green plants starve.

2. Mention the word which is the lesson.
3. What plants live by it?
4. What plants can live without it?
5. Are such plants of a high or low order?
6. Name the parts of a plant which grow to full size without light.
7. What plant food can be made by light only? Of what importance is this food? To what sort of plants indispensable?

I. **Without light, green plants starve, for they manufacture starch by it only.**

NOTE. — Plants which get their starch from other plants can live in the dark. Plants which live upon decaying matters grow and perfect fruit in caves and cellars.

TESTS.

(1)

Search dark cellars and host plants for the following, and describe their condition when found: —

(*a*) fungi.
(*b*) mildew.
(*c*) rust.
(*d*) yeast plants.
(*e*) slime moulds.

Tell which of the following must have light: —

verbena blossoms.
a leaf of verbena.
a root.
stems of Indian corn.
flowers of Indian corn (tassels and silk).
smut.

(2)

Box up a flower-bearing end of a melon vine, exclude all light, and watch results.

Report the development of the flowers in respect of size, color, shape, and strength.

How can winter pears and apples "ripen" in the house?

B.

MOVEMENTS OF PLANTS.

Mention visible movements of the following plants, and tell when they occur: —

four o'clock, leaves of clover,
sensitive plant, dandelions.

What is true of all plants?

II. **Every plant can move itself. Many plants are much more active than the lowest animals;** as, —

sensitive plants, some cassias.

What is sufficient to irritate a sensitive plant? Where is it most irritable?

ANS. *In its younger tissues.*

NOTE TO TEACHER. — Grow sensitive plants in the schoolroom for study. Seeds may be had for a few cents, and are easily grown.

Is the sensitive plant an exception in the plant world, or an intensified example of a power owned by every plant?

Describe the movements of, —

oxalis, parsley, a strawberry geranium,
sunflowers, the water lily, fuchsia leaves.

Name some plant, and describe its movements toward the light, away from the light, or its manner of adjusting itself for sleep.

When a seed sprouts, how does its root always move?

Sundew.

III. **When a seed sprouts, the little root tries to move in circles;** thus, —

Sprout a bean, and fasten it carefully under a cork in a bottle of water. Watch the movements of the protruding rootlets.

IV. **The tip of the root is sensitive to pressure, and when it touches any object, bends from it.**

Therefore the root tip guides the root through the ground, avoiding stones and hard lumps.

V. **Root tips are sensitive to moisture, and are always leading the roots to wet places in the soil.**

Write five statements about the movements of roots of plants, and describe the route they take through the earth.

Tell how the revolving motion of the root aids it to find soft places in soil.

Tell whether roots are often found in true spirals, and think of a reason why they are more or less deformed.

VI. **Every growing shoot and every flower stalk endeavors to grow in spirals**; thus, —

a bean stalk, a pea plant.

Tell how the branches of the following grow: —

an acacia tree, a maple, a geranium shrub,
a pine, a rose tree, blackberry bushes.

Write two statements about the movements of growing stems of trees and shrubs, and of annual plants. (*Annual* means living but one season; as, mignonette.)

Describe the real movements of any large tree, as to both stem and root, and state whether we can see these movements, or only their results.

We do not know why growing parts of plants above ground revolve. There may be preferences in air currents and densities of the air. The plant may seek these as specially good points for spreading out its leaves.

Exercise I.

Name a plant whose name signifies "turning to the sun."

Give another, that lives away from the light.

Mention three plants which change position at night.

Make notes of day positions of the leaves of five plants.

Make similar notes of the night positions of the same plants.

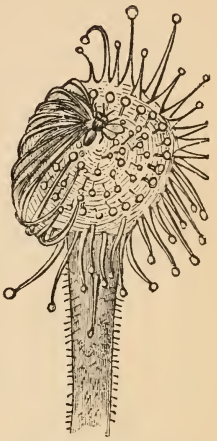
Are all plants able to move?

Name parts of plants that seem motionless.

Name others that prove they are in motion.

Mention a plant with visible movement.

Tell two reasons for the spiral movements of a root.



Sundew Leaf holding a Fly.

Exercise II.

1. Draw a sketch of the day and night positions of a daisy.
2. Study a fuchsia in a window, and write an account of its movements toward the light.
3. Sow seeds in a window box, and carefully study the tiny plants that appear. Make notes of your work, and embody these notes in a composition about plant movements, marking particularly, —

   (*a*) any stems or runners that bend away from the light. By experiment prove the plant's persistence in its habit.

(*b*) leaves and stems which turn towards the light.
(*c*) differences of position during waking and sleeping states. The bean family are excellent examples for this study.

4. Sprout cabbage seeds, and examine the *first leaves* of the seedlings. These first leaves, by the way, are always called in botanical works *cotyledons*. Mark, —

(*a*) their positions by day.
(*b*) their positions by night.
(*c*) if they invariably rise at night.

C.

MORE ABOUT THE MOVEMENTS OF PLANTS.

Describe the particular form of movement which you found was possessed by, —

oxalis,
the strawberry geranium,
the heliotrope,
roots of beans.

Mention the general law of movement of all growing roots and stems.

The law of progress in spirals is modified by certain influences; as, —

At night the leaflets of oxalis bend down and cling about the stalk.
At night clover leaflets fold to one side and bend upwards.

The leaves of most plants take a different position at night. Their growth in spirals may be hindered by the withdrawal of strength-giving light.

Strong light stimulates * plants so much that they bend towards it. Their perfect progress is thus destroyed.

Dictate a statement which shall describe a motion common to all plants.

Change the statement so as to correctly give two hindrances to the plant's power to describe circles.

How does the turning stems to the light prove their original circular movement?

Leaves and stems move in a zigzag course toward the light.

Pitcher Plant.

Is the course ever a straight line?

Nearly a straight line, at times, in a flood of light.

Give from your observation the amount of light (as *common daylight*, *noonday sun*, *hot rays on glass*, etc.) necessary to turn a stalk or leaf from its course, to bend it visibly toward the light, and to draw it out in a straight line.

Pin a sprouting bean with the rootlets upward. Which way will they grow?

---

* Note to Teacher. — Explain *stimulates*.

Roots of ordinary plants will always bend toward the earth; as, —

the rootlets of strawberry plants.
the edible roots which we draw from the ground.

VII. **Turning toward the light and turning toward the earth both depend on the continuous motion of the plant. This motion is as tireless as are our heart-beats, during every minute of the plant's life.**

Hard substances in the soil will modify the spiral movements of roots, and places of much moisture will have the same deflecting fascination which light has for stems and leaves.

GRAVITATION, — *a force which keeps you and me upon the earth, — draws roots down, and modifies their circular sweep.*

TEST I.

How do leaves and stems usually move toward the light?
Which way will roots always bend?
Make a statement about the influence which modifies growth in spirals in the case of, —

a root,	cotyledons of cabbage,
a clover leaf,	flowers of four o'clocks,
heliotrope,	leaves and flowers of the dandelion.

Change the statement so as to mention some other plant.
Read the following list of plants, —

date palms,	anemones,	lilacs,
trailing arbutus,	orchids,	seaweeds.

and tell in each case towards what the root bends.

Correct, —

(*a*) Plants are motionless.

(*b*) The thick-walled tissues of plants are most sensitive.

(*c*) The sensitive plant does not shrink when touched.

(*d*) Leaves and stems hurry in straight lines toward the light.

Test II.

Tell what parts of what plant, —

move in circles.

are weakened by the withdrawal of sunlight.

are greatly influenced by bright light.

seek soft places in the soil.

lead roots to spots of moisture.

Test III.

Describe the movements of the root and stem of a heliotrope, and state what is the basis of any sort of particular movement of any plant.

What certain rule for the direction of ordinary rootlets?

What causes this certainty?

Define gravitation, and use it in a written statement about, —

(*a*) three objects in the schoolroom; as, chair, desk.

(*b*) three objects in the street, or in a shop, or in the school-yard.

(*c*) a horse hauling a load or drawing a carriage; a cow standing under a tree.

(*d*) teacups upon the table; the china in the cupboard; the stove upon the floor.

(*e*) water in the ocean, or in a river, or in a well.

(*f*) the roots of plants.

In other statements, describe its hindering force with regard to the law of plant movement in curves.

Give reasons for other hindering forces to the spiral movement of roots.

How do leaves and stems usually move to the light? When greatly stimulated?

Give the general law of plant movement. Name three modifying influences. Give an example of each.

Describe the position during sleep of, —

leaves of { oxalis, clover, } cotyledons of { celery, cabbage, }

sensitive plants,

flowers of the water lily.

Use these descriptions in statements (*a*) telling the modifying influence, (*b*) describing the plant action under the influence.

Review.

ORAL.

1. What per cent of water in a higher flowering plant? In seaweed? What parts of plants are abundantly supplied with water? What absorbs it? Why? Tell its office in cells. In cell-walls.
2. Define a *cell-wall*. How and where do cell-walls thicken?
3. Describe the condition of water in a plant body during winter. Give three disturbing agencies in summer. How is water a plant material? How is water absorbed by, —

   deep-sea plants?

   land plants and parts of plants above water?

4. Explain these terms: —

evaporation,	"circulation of sap,"
breathing-pores,	perennials,
movement of water in plants,	annuals.

5. Define plant food, and use it in a statement.
6. Give two statements about plant food, mentioning (*a*) one food common to the animal and plant worlds; (*b*) habits of eating of different plants.
7. Which holds the most food materials, well water or pond water? What process aids the transportation of food? Which order of plants has a complex diffusion of food materials?
8. What is starch? Where is starch-making done? Name other products made in the green parts of some plants.
9. Tell how (*a*) starch is of use, (*b*) its change upon leaving its factory, (*c*) its change again before storage. Tell (*a*) why any food material is stored, (*b*) upon what the organs which have no chlorophyll depend.
10. (*a*) Define *lowest*, *best*, and *highest* temperatures.
    (*b*) Give the lowest, best, and highest temperatures for plants.
    (*c*) Illustrate how the best temperature varies for different parts of the same plant.
    (*d*) Would green plants starve without light?
    (*e*) Name a cousin of green slime.

    Ans. *Red snow plant.*

    (*f*) What plants can live in the dark?
    (*g*) Has every plant the power of motion?

(*h*) Name the plant having this power in the highest degree.

(*i*) Give the real direction of plant movement.

(*j*) Mention three modifying influences over plant movement.

BLACKBOARD.

1. Write a proof of the abundance of water in some seaweeds.
2. Write the composition of the growing point of a plant.
3. Write a statement that tells (*a*) agencies which disturb water in a cell, (*b*) how vacancies in cells are filled.
4. Write the relative rapidity of evaporation in, —

   a wet day,
   a dry noon,
   the night.

   Write a definition of breathing-pores, with their location. Use the word breathing-pores in a statement about a function which they directly control.
5. Write carefully the reason of the flow of sap from the sugar maple.
6. Write the route of water in plant structures. Write Three Things to Remember about water in plants.
7. Write statements telling whence the following obtain their food: —

puff balls,	red seaweeds,
pond lily,	lichens,
Venus's fly-trap,	primroses,
smuts,	mosses.

8. Describe in writing the diffusion of plant food, telling (*a*) a reason for the unequal transportation of foods through the tissues, (*b*) what great food holds many other foods in *solution;* that is, *mixed inside its own structures.*

9. Use in written statements, —

starch,	squash seed,
sugar,	potato,
chlorophyll grain,	bulbs.

10. Write a paragraph (*a*) about the apparent best temperature of three common plants which you know, or of which you have read; (*b*) about their continuous movement, its direction, and whether the movement is visible to your unaided eyes; (*c*) about the influence of light upon their natural movement. Add the names of plants found in cellars and caverns, and account for their life without light.

11. Which requires the higher temperature, —

tassels and silk of Indian corn?
the blade of Indian corn?
the root of Indian corn?
an anemone?
a Jacqueminot rose?
an aster?

CHAPTER IX.

THE PLANT BODY.

A.

THE PLANT BODY.

Green slime, pond scum, sea lettuce, kelp.

The simplest plant bodies are masses of houseless protoplasm.

The next higher are plant cells living alone, or in rows, or in cell surfaces.

I. **The body of the lowest plants has no root, stem, or leaf;** as, —

yeast,	kelp,
bacteria,	diatoms,
slime moulds,	black mould.

II. **Higher plants divide as they grow into many forms. Each form has a different composition and particular use;** as, —

tendrils of pea,	flower cluster of aster,
thorn of plum,	tubers of potato.

CAUTION. — *Large seaweeds appear to be developed into stock and leaves; but the division is somewhat unreal, as in spite of the fact that the poor things do their*

best, they have not developed very good stem and leaf systems from their simple structures.

Tasks.

(1)

Study with the microscope examples of the four plants at the beginning of the lesson.

Do these plants belong to high or low orders?

Use the following names in statements: —

yeast, kelp, black mould.

Write the statements so that they will tell where the plants are found.

Use the following names of plants in statements, telling whether they belong to high or low orders: —

Irish Moss.

the water lilies,	magnolias,
linden trees,	the rose family.

Classify these: —

red seaweed,	wheat rust,
daffodils,	barberries.

(2)

Write an example of the simplest plant body.

Tell by examination whether the following *appear* to have members: —

sea lettuce,	rockweeds,
kelp,	lichens.

Write the name of a plant which is an example of, —

a single cell.
layers of cells.
rows of cell surfaces resembling leaves.

Do you scrape high or low orders of plants from pepper grass? grape leaves? garden lettuce?

Write a statement about, —

large seaweeds, masses of mould, rock lichens.

Correct mistakes of fact: —

Yeast belongs to a high order of plants.
Geraniums are masses of naked protoplasm.
Rockweeds have roots, stems, and leaves.
White rusts are entirely marine.
The flowering plants have undeveloped bodies.

(3)

Tell whether the plant body of each of the following is one or many celled; whether it has one or many tissues; and if it is memberless or not: —

(*a*) a pine tree.
(*b*) red rust upon oats or barley.
(*c*) "cedar apples" on red cedar twigs.
(*d*) a fuchsia plant.
(*e*) the mosses.

Tell which plants are of high orders, and which of the low orders.

Of what is the lowest order of plants made?

Define protoplasm. In what is it usually boxed?

Write upon the board a statement containing the name of a very simple plant, and of a very complex and high-ranking plant. Write another statement, with all the points of difference between them which you can notice.

B.

STEMS.

A potato *is an underground stem.*
The so-called root *of a* gladiolus *is a fleshy stem.*
A strawberry plant *is a prostrate stem.*
"Sweet flag-root" *is a fleshy, underground stem.*

Passion Flower.

Does a plant in its earliest stage possess a stem? When does the stem develop?

It is a member of what?

ANS. *The plant body.*

Are all members of the stem like or unlike in the earliest stage of stem life?

Prove your decision by bulb stems, and by stems upon which flowers rest.

Describe any familiar common stem.

Tell how a potato differs from an aerial stem.

Give another example of stems thickened into fleshy knobs.

Give differences between the underground stem of a gladiolus and that of a potato.

Give the common name of prostrate stems.

Describe a runner, and give an example.

How does the stem called "sweet flag-root" differ from the underground stems above mentioned?

Study a specimen with joints and branches. Blood-root is a good example.

1. *Branches are stems developed from other stems. The usual stem is a bundle of tissue systems plainly arranged for strength, and bearing leaves.*
2. *A runner is a weak and trailing stem;* as, the strawberry plant.
3. *A root stock is a fleshy, weak, generally underground stem, developing horizontally with branches;* as, sweet flag.
4. *Corms are fleshy, underground, leaf-bearing stems;* as, the crocus, gladiolus.
5. *Tubers are stems swollen to knob-like reservoirs of plant food. They are underground stems and bear small leaves called scales;* as, the potato.
6. *Bulb stems are underground stems, short and leaf-bearing;* as, the bulb stem of the onion.

Tendrils.

7. *Tendrils are slender, air-growing stems made so largely of fibrous tissue that they are seldom leaf-bearing.*

8. *Thorns are thick, aerial stems nearly destitute of leaf material.*
9. *Flower stems are aerial and usually short. From them are developed leaves, floral envelopes, and the very flowers.*

Task.

Give an example of, —

(*a*) a stem which is named, —

(1) a corm.
(2) a root stock.
(3) a bulb stem.
(4) a tendril.
(5) a thorn.

Iris.

(*b*) a runner; an ordinary stem.

(*c*) a flower stem. Give the plant members developed by the flower stem.

Tell what you have learned about the development of stems from the plant body.

Describe the condition of the lowest orders of plants.

What is true of any plant in its youngest stages?

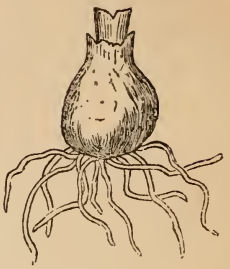
Give the proper name of, —

a potato,
"roots" of the gladiolus,
a strawberry plant,
"sweet flag-root."

Potato.

1. Write a statement about the stem of a geranium.
2. Write another, about the runners of the strawberry.

3. Rightly name, spell, and write the "roots" of blue grass.
4. Locate the real roots of potato plants. Write differences between the real and the apparent roots.
5. Write the real name of so-called crocus roots.
6. Write a careful description of the stem which produces the onion, with its proper name.



Hyacinth.

7. Write the name of the stems by which Virginia creepers climb.
8. Write five examples of flower stems.
9. Describe dwarfed, rigid stems found upon rose bushes.

C.

LEAVES.

A. *A leaf is a broad surface designed to spread as much plant tissue as possible in the air and the light. It is full of chlorophyll cells.*

Bracts are small leaves, with or without chlorophyll stains.

Scales are tough and rigid leaves without chlorophyll cells.

Floral envelopes are delicate and velvety leaves. They possess more or less chlorophyll.

Sessile. Stalked. Sheathed.

Stamens are leaves oddly developed into stalk, pollen box, and pollen.

Carpels are leaves folded into slender holders of pollen.

B. *At the bases of flower clusters of golden rod or asters you will find bracts. Buds are protected by scales;* thus, — lilac buds are wrapped in scales.

Write and use, —

stamens, carpels, floral envelopes.

Cowslip Leaf.

Flag Leaf.

C. *Root-hairs are forms of leaves;* as, the root-hairs of a radish.

1. Describe the floral envelope of a tulip, a rose, a buttercup.

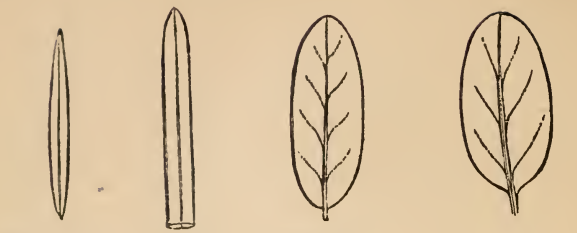
The stamens and carpels make up the true flower.

Alternate Arrangement.

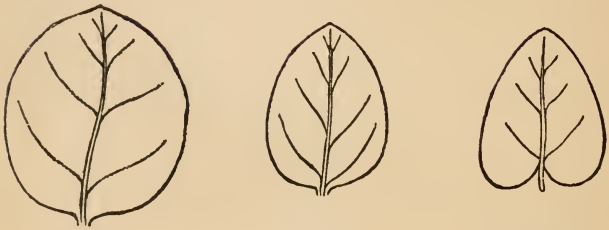
Opposite Arrangement.

Whorled Arrangement.

2. Describe the true flower of an anemone or a lily. The stamens are forms of what? The carpels?



Needle-shaped. Linear. Oblong. Oval.



Rotund. Ovate. Heart-shaped.

Kidney-shaped. Lance-shaped. Broad-blade-shaped. Spear-shaped. Arrow-shaped.

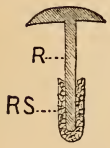
Shapes of Leaves.

3. About what forms is this lesson? Are all these forms true leaves, or equivalents of true leaves? Give the names and shapes of six true leaves.

D.

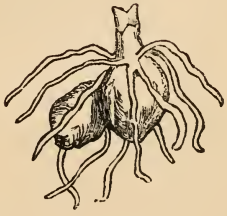
ROOTS.

Name a root, and tell me something about it; as, beets are thick, long roots.



Root-Sheath in Duckweed.
R. root.
R.S. root-sheath.

Fibrous Root.



Tuberous Root.

Tap Root.

State something about, —

a turnip, grass roots, roots of the buttercup.

Tell me how roots of *trees* and *shrubs* differ in appearance from these.

Roots of trees are woody, and have numerous branches. Roots of buttercups grow in clusters. Grass roots are like matted threads. A turnip is a short, swollen root.

Where are all these roots found?

III. **All common roots are found in the soil.**

IV. **The roots of a young plant appear later than stems and leaves. They are found only in high orders of plants.**

A root is a development of plant tissues for food-conducting purposes. Incidentally, it is a means of location.

V. **Roots sometimes live in the light and air. These are aerial roots. Visit a greenhouse and study the aerial roots of orchids. Notice the greatly thickened skin.**

VI. Roots of plants living off other plants are found above ground. Their rootlets bury themselves in their hosts.

Read the following list. Copy all names of plants having underground roots: —

(1) radish,
(2) grass,
(3) mistletoe,
(4) lady's slipper,
(5) cabbage,
(6) orchids,
(7) lichen,
(8) dodder vine,
(9) grain,
(10) maples.

Draw a line under the names of plants with aerial roots; with *parasitic* roots. *Parasite* means *living upon another.*

CHAPTER X.

LIFE AND HOME OF PLANTS.

A.

HOW LONG PLANTS LIVE.

(*a*) Annuals die in autumn.
(*b*) Perennials survive the winter.

(*a*) The sweet pea is an annual.
(*b*) Peonies are perennials.

Plants that live but one year are called *Annuals*.

The word *perennial* means "living through the year": currant shrubs are perennials.

Most plants are very short-lived. Most of the plants we see about us die before cold weather.

Plants are constantly dying and are constantly springing up all over the world.

Speak the names of the following plants; as you give each, mention whether it is an annual or perennial plant: —

oleander,	hyacinth,
Japanese quince,	day lily,
lady's slipper,	phlox.

Rye Grass.

Timothy.

Sand Grass.
It has been used in Holland for checking encroachments of the sea.

Tell which of these perennials outlive the others: —

currant shrub,	onion,
cactus;	calla;
peony,	grass,
aloe;	palms;
dahlia,	elm,
century plant;	yew.

Sometimes plants die more rapidly than they are renewed. In time, such plants become extinct.

"*Extinct*" *means* not found in the world.

Sometimes new forms of plants appear, and species of plants become very much changed; thus, in our time, the tulips are made to vary extremely by cultivation.

Tell which of the following are cultivated varieties, and what varieties tend to do: —

sweetbrier rose,	"black roses,"	violets,
Marechal Niel,	"black tulips,"	pansies.

You have seen fossil plants imbedded in sections of rocks. Going backward in time, plants grow more and more like them, and less and less like those we see. The diatoms of deep-sea ooze were once the plant world. The relations of the grasses, the oaks, and the maples, and all the food-furnishers date back to the age when the "chalk cliffs of Albion" were formed. The lilies are old; so are orchids. The coal we burn is the dead wood of long centuries of giant ferns.

Write at dictation, and use in statements about their special points and values, —

Names of plants that live one or two years, —

potato, tobacco,
cucumber, mints,
cotton, heliotrope,
poppies.

Names of plants lasting many years, —

(1) birch, (6) pears,
(2) maples, (7) quinine tree,
(3) willows, (8) cat-tails,
(4) cranberries, (9) palms,
(5) huckleberries, (10) rushes.

Test I.

WRITTEN.

Write a word that is a name, —

of an annual.
of a plant that lives many years.

Write six names of plants in the yard at home, or in the schoolroom, and tell if they are varieties produced by cultivation.

Write the name of (*a*) a variety of rose produced by cultivation; (*b*) a variety of tulip. Describe in writing a wild rose.

Define in writing a *floral envelope*. Use this name in a statement defining the differences of the floral envelopes of wild and cultivated roses.

Write the name of a plant often found in coal.

Write a statement about the character of the plant world in the early ages of our earth.

What orders of the plants of our time seem most like the fossils?

Low orders of present plants are much like the fossils. The diatoms still cling to submerged sticks and stones, and are dredged from deep-sea water.

Test II.

ORAL.

(*a*) Water moulds are generally found attached to the bodies of dead fishes.

(*b*) Have mosses roots?

(*c*) Seeds of grasses have a copious starchy deposit.

(*d*) Bananas furnish great quantities of food.

(*e*) Sea lettuce is common along the coast.

Underline the names of long-lived plants.

Draw two lines under the names of water plants.

Answer the question.

Name four edible seeds of grasses.

What climate produces bananas?

Mat Grass.

"It has been found so useful for binding blowing sand that Acts of Parliament have been passed prohibiting its destruction under severe penalties."

Test III.

WRITTEN.

Write statements in which you use correctly, —

life, long, short, plants, years, centuries;

the name of a very long-lived plant.
a short-lived plant.
a plant of very long ago.
a plant family as old as chalk.

B.

WHERE PLANTS MAY LIVE.

In what climate are plants most abundant?
What besides temperature controls vegetation?

Moisture controls vegetation.

Primroses.

Upon what does temperature depend?

Much upon the amount of light. The poorly lighted polar circles have deficient vegetable life. The ocean depths have an equally scanty number of plants.

What control has moisture upon land plants?

The character of the annual rainfall greatly determines the conditions of land plants.

Warmth, and the direction of rivers in the sea — called ocean currents — decide the types of both vegetable and animal sea life.

Marsh Marigold.
"The wild marsh marigold shines like fire in swamps and hollows grey."

In what places upon the earth will vegetation be similar?

Vegetation will be much alike in all parts of each climactic belt.

Exercise.

(With the Teacher.)

1. Find on the map of the world, —

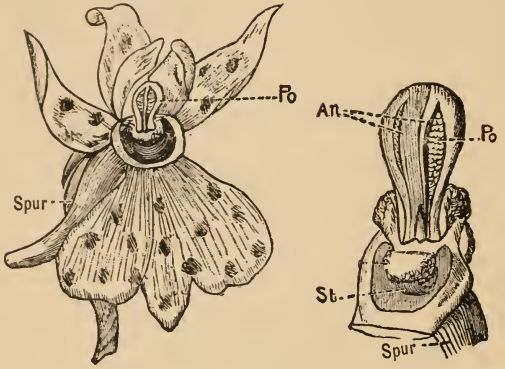
   A forest region of the Eastern hemisphere which is the counterpart of the American forest region.

2. Of what in our country is the steppe region of Asia a counterpart?
3. Give two points of resemblance between the Californian and the Mediterranean regions.
4. To what does the plant life of the Pampas to a great degree correspond?
5. Why is the same sort of vegetation found on Prince William's Land and upon the tops of the Alps, in the heart of Europe?

Pollen Mass. Bee after Honey.

Bees' Heads with Pollen.

In *a* the bee withdraws his head from the flower.
The pollen mass falls by the time he reaches another into the position *b*.



Spotted Orchis.

Po. pollen; *An.* anther; *St.* stigma.

EXPLANATION. — The honey is in the spur of an orchis, or a nasturtium, or a larkspur. A bee pushes his hollow tongue down it as far as he can, and withdraws his head decorated with the two pollen masses which are set at the entrance. He deposits them upon the stigma of the next flower visited.

6. Name the controlling agents which developed the plant life of the valley of the Amazon; the period of coal in a long-past age.
7. Decide whether plants of high or low orders will be most widely scattered over the world.
8. Give a reason for your decision.

APPENDIX.

SOMETHING ABOUT MICROSCOPES.

Microscopes are of two classes, simple and compound. A simple microscope produces the image by refraction through a single convex lens, or several thin lenses placed together and acting as a single lens. In the compound microscope a very bright enlarged image is made by a lens or a combination of lenses called the *objective*, and this image is viewed and again magnified by means of a simple microscope called the *eye-piece*. The eye-piece is placed at the upper end of the brass barrel, or working tube. The area of the image depends upon the relative distances of the objective and eye-piece, so that the instrument should be provided with a "draw-tube," that its magnifying power may be increased without a change of objective or eye-piece.

The essentials of a good practical compound microscope are a steady stand, provided with an accurately centred stage to which the glass slips can be attached; a plano-concave mirror that can be swung above and below the stage for both transmission and reflection of light; and a working barrel with draw-tube. The working barrel should be provided with both a coarse and fine movement for rapid and careful adjustment of the lenses to focus. Most of even the cheaper stands are now provided with

the "society screw." This should be insisted upon when purchasing, in order that objectives of any make, and of the better as well as the cheaper grades, may be used upon the instrument when desired.

A stand which will meet every requirement of this work, and be fully adequate for more extended research, together with one good eye-piece can be purchased for about $25.00. To this should be added two objectives, one with a 1-inch focus, costing $6.00; the other, a $\frac{1}{6}$-inch focus at a cost of $16.00.

A pair of long, pointed, sharp scissors, several needles inserted in wooden handles, and a shallow glass dish are essentials for manipulating tissues.

MOUNTING. It is necessary for success in teaching to have a supply of prepared specimens, which can be mounted by the teacher much more cheaply than they can be purchased, and, after a little experience, will be much more satisfactory. Specimens should be nicely centred upon glass slips three inches by one inch in size, and protected by thin glass covers, which can be purchased in shapes square or circular.

It is not economy to use poor and thick glass for either slips or covers. The mounting medium will often fasten the cover to the slip sufficiently. For added security it is well to fasten down the edge of the cover with asphalt varnish, marine glue, or gold size, which is much better than either.

For a mounting medium for tissues that are not too moist, pure Canada balsam dissolved in chloroform is recommended. As many tissues *are* too moist for Canada balsam, it is necessary to say that glycerine-jelly, which can be bought of any optician, is the best for the beginner.

The amateur will find invaluable hints and directions in regard to work with the microscope in Dr. J. G. Wood's little book, "Wonders of the Microscope," which can be bought for seventy-five cents. Dr. Carpenter's work on the Microscope contains very complete directions for mounting every kind of tissue. *To the fullest equipment and most exhaustive directions the novice must add patience, and a determination to make present failures contribute to future successes.*

Care of Microscope. The objectives and eye-pieces must be kept scrupulously clean. The surfaces of the lenses are clean when the condensed breath upon the glasses almost instantly disappears. Eye-pieces may be taken to pieces, and thin lenses cleaned with a soft handkerchief and alcohol. Brush the dust from your objectives with a camel's-hair brush. Under no circumstances attempt to take them to pieces. That is work proper for skilled hands only. In all work with the microscope be neat, methodical, and painstaking.

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